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SEPTEMBER 1956

VOLUME 73 **NUMBER 3**

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A.M.A. Archives OF SURGERY

The Obligations of Achievement

RUDOLF J. NOER, M.D., Louisville

Just 15 years ago, on Feb. 28, 1941, Dr. Roy D. McClure delivered the first Presidential Address before the newly organized Central Surgical Association. Speaking at the Michigan Union, in Ann Arbor, Mich., he outlined the ideas which had stimulated its formation and reviewed the objectives and ideals which guided the founders in its inauguration. The immediate and widespread acceptance of this new society and its continuing and sustained success bear testimony to the soundness of the principles upon which it was founded. Today, upon the 15th anniversary of that first meeting, it is appropriate that we who have enjoyed its many benefits should review its background of achievement and consider together the obligations which have thus been placed upon us for the future of this important Association.

Early discussions on the need for this type of organization began about 1938 or 1939, but the first record of activity is a letter sent by Dr. Roy D. McClure, early in 1940, to a group of American Surgical Association members. He asked for opinions regarding the need for such an organization and the possibilities which it might offer. Certain portions of his letter are of particular interest: "In our section of the United States the more promising younger surgeons do not have the opportunity for self-expression and stimulation of friendly and intimate contacts with each other that are open to men of similar abilities and aspirations in other parts of the country. There is real place and purpose for a central [states] surgical association. I know of a dozen eligible, grade A, high-class, young surgeons in Detroit and Michigan who would be excellent material . . . and I have good reason to believe that other cities in the central states have similar groups of eligible men." On March 23, 1940, he wrote that 22 replies had been received, 18 of them favorable, some enthusiastic, 3 lukewarm, and 1 opposed to such an association. As a result, a series of meetings took place, during the course of which the new society gradually took form and finally was incorporated as the Central Surgical Association. Two basic problems seem to have concerned the founders: first, the lack of a small, regional surgical association in the Central States area, comparable to those existing in the New England, Southern, Western, and Pacific Coast areas, and second, the need for what seemed nowhere to exist, a forum where promising young men could present their ideas and participate actively in a surgical organization of their own.*

After a preliminary gathering in Detroit, on April 2, the organizational meeting was held in St. Louis, on May 1, 1940, with 21 members of the founders' group, all Fellows of the American Surgical Associa-

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* The Surgical Forum of the American College of Surgeons was developed at about the same time.

tion, present. Dr. McClure was elected Acting Chairman, and Dr. George Curtis Acting Secretary. These two men, perhaps more than any others, deserve credit for the zeal and unflagging spirit with which they promoted the development of the Central Surgical Association. A resolution calling for its organization was adopted, and this became the preamble to the constitution. The remainder of the meeting was directed to the development of a constitution and bylaws, and to other basic needs. Three forms of membership were decided upon—active, senior, and honorary, with the active membership limited to 100. Officers elected for 1940-1941 were as follows: President, Roy D. McClure; President-elect, Grover Penberthy; Secretary, George Curtis; Treasurer, Max Zinninger; Recorder, Henry Ransom, and Councilors, Kellogg Speed for one year, Vernon David for two years, and Carl H. Lenhart for three years. It was also decided that the first meeting would be held at the University of Michigan, in Ann Arbor, during the latter part of February, 1941.

A second meeting was held at the Ford Exhibit, New York World's Fair, on June 12, 1940, and a third in the Detroit Club on Sept. 25. These two sessions were devoted to selection of founders and founder members and to plans for the first meeting to be held at Ann Arbor in February, 1941. It was agreed to "keep the Association young and inexpensive." Considerable discussion occurred with respect to geographic distribution of membership and the question of publication of proceedings and papers.

The final meeting of the founders group was held in the Stevens Hotel, on Oct. 23, 1940, at which time membership lists as of that date were approved. It was decided that there would be no geographic restriction of membership, and that members would not be restrained from joining any other surgical association.

The First Annual Assembly of the Central Surgical Association took place on Feb. 28 and March 1, 1941, at Ann Arbor, Mich. The choice of this location no doubt reflects the interest of Dr. Frederick A. Coller in the new organization and his long friendship and association with many of the founders. An invitational clinic day at the Henry Ford Hospital, in Detroit, preceded the regular meeting and included presentations by members of that staff and of the Department of Surgery of the Wayne University College of Medicine. This preliminary clinic day established a precedent, which has continued to this day. A reception for members and guests was given at the Dearborn Inn that evening, and the formal program followed on Friday and Saturday at Ann Arbor. The council added 30 surgeons, 14 of them from Detroit, to the original founder members' group. The secretary explained that the "founders" actually were those Fellows of the American Surgical Association particularly interested, and that the "founder members" were young men "particularly associated with the founders . . . and . . . sponsored by the founder's group." With respect to the new names he added, "the following names, which have been elected to membership, were proposed originally to the officers by the various sponsors . . . and the men were recommended by our membership committee to the council. The final action of their election has been made by the council, and as Dr. McClure has explained to you, this is the last of the choice of our so-called 'founder members'— that is, the ones who have been chosen by the sponsors of this association." This made a total of 42 "founders" and 107 "founder members."

Thus a new and important surgical association came into being and was well along its way toward success. The unique sponsorship by founders from the American Surgical Association had assured what might be referred to as a "running start," and the first meeting in Detroit and Ann Arbor fulfilled and went beyond the fondest expectations of those who planned it.

A second meeting held at the Drake Hotel, in Chicago, was well attended, and the program upheld the high standard of scientific excellence set at the first meeting.

Acceptance on the part of the profession in the Central and Great Lakes areas was immediate, and even enthusiastic. As might be expected, recognition on the part of established organizations was less spontaneous. It is interesting to note an exchange of letters between Olin West, then secretary of the American Medical Association, and Dr. McClure, relative to a listing of the Central Surgical Association among the national organizations. Dr. West indicated in his letters that it obviously was impossible to include all of the medical organizations in their listing, while Dr. McClure protested that if any regional organizations were to be listed, there was no reason to make an exception in the case of the Central. Question was later raised by the society about a representative on the American Board of Surgery, and the reply was this was not possible. The later, complete acceptance of the Association by the American Medical Association is familiar to all, and it is of particular interest that the American Board of Surgery, in 1952, requested the Central Surgical Association to supply a member for that Board. In the same year, a Governor of the American College of Surgeons was for the first time selected from our membership.

Four persons, more than any others, appear to have been responsible for the development and sound beginnings of the new society: the first presidents, Dr. Roy D. McClure, Dr. Grover C. Penberthy, Dr. Roscoe R. Graham, and the first secretary and later president, Dr. George M. Curtis. Many of the ideas of these men with respect to the new organization appear in their presidential addresses. Dr. Roy McClure (Fig. 1), speaking on "The Inauguration of the Central Surgical Association," said, "My election to this office is probably a token of recognition of a role played in the formation of our society, and while it is true that the concept of the organization originated with me . . . the greater credit of its sound foundation belongs to those Fellows of the American Surgical Association who have agreed to act as its sponsors. . . . Some years ago I came to realize that a great many able, well-established, and excellently qualified surgeons had been barred from inclusion in the senior surgical societies, mainly because of the 'closed number' policy, while the oncoming generation of young men who have an increasingly better foundation training had even less chance. . . . I could not help reflecting on the curious circumstance that of all the important cartographic divisions of our country, the potentially most important one, the Mid-West, was the only one lacking its own surgical society. These considerations made it clear that an unmistakable need existed for a surgical society with its headquarters in the Central and Great Lakes region. . . . This society has been projected as a proving ground for young surgeons . . . a stimulus when this is most needed; as a bridge between the time of completion of residency, acceptance by the Boards, and arrival at the period of recognition as surgeons—a time interval during which many young surgeons stagnate through inaction and lack of stimulation by a scientific surgical society. . . . I was interested to note that times and people change but little, for those who demurred offered the same objections as those advanced by the opponents of Samuel Gross and the other founders of the American Surgical Association, in 1879. The claim was made then, as now, that with the country full of all sorts of surgical societies there was no need for such an organization. The suggestion has also been made that this society might encroach upon the regional meeting of the American College of Surgeons in this area. In reply to this charge, I can do no better than again quote the words of Samuel Gross when he was similarly accused of striking a blow at the American Medical Association: 'We can hurt no society now in existence or likely to come into existence. We can hurt only ourselves if we fail to do our duty.'

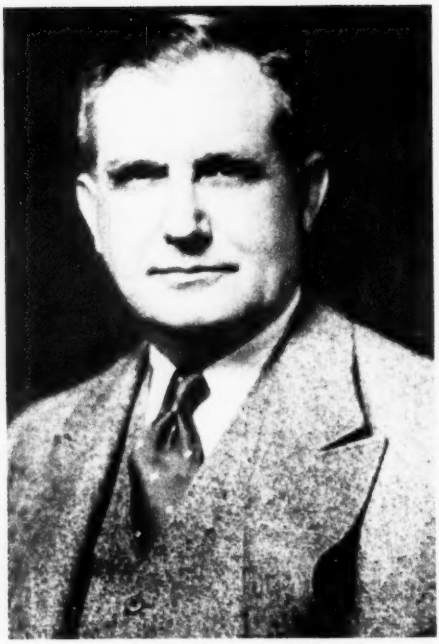

Fig. 1.—Dr. Roy D. McClure, first president of the Association.

Fig. 2.—Dr. Grover C. Penberthy, second president of the Association.

Fig. 3.—Dr. Roscoe R. Graham, third president of the Association.

Fig. 4.—Dr. George M. Curtis, first secretary and fifth president of the Association.

"All medical organizations have been started with the same high ideals, namely to promote the art and science of medicine, to encourage the acquisition of knowledge by their members, and to aid in the improvement of the general health of the community. Too often these ideals have been lost sight of because attention has been focused on what seem to be more pressing problems involving the welfare of the members. It is my belief that such matters as medical ethics, medical economics, or medical politics have no place in a purely scientific organization. Let us then resolve to abstain from the discussion of all such irrelevant questions and direct our energy toward developing better surgeons and thereby to improve the practice and knowledge of surgery. If this goal can be achieved, problems of ethics and policy will solve themselves."

The second president, Dr. Grover C. Penberthy (Fig. 2), on assuming the chair pointed out, "A new surgical association has been born and christened. The sponsors . . . have given this organization a great deal of thought. . . . This is an opportunity not for the individual who has arrived as a surgeon . . . but an opportunity for the individual who has had the opportunity of training . . . and still has the interest to go forward to lead us into the field where we can feel secure and know that Surgery is being practiced as we who are trained know that it should be practiced. . . . The pattern has been set for this Society and the ideals are high, it rests with the young men to carry through."

It is significant that the third president came from our neighboring province to the north, Dr. Roscoe R. Graham, of Toronto (Fig. 3). This early association between the United States and Canada has been one of the potent factors which has made this organization strong. From the beginning this relationship has been an intimate and a cordial one. Dr. Graham in assuming the chair referred to this: "It is with a very definite consciousness that you are paying tribute not to the individual but to Canadian surgery and to our school that I thank you for this honor. . . . The spaces over which we are scattered in Canada are so vast, the numbers are so small, that the generous gesture which you have made to us in including us in your national organization and giving us all the opportunity to profit by your presentation we appreciate more than you know. . . . While I would be less than human were I not greatly flattered as an individual by your gesture of kindness, I am proud to represent Canadian surgery and the University of Toronto and to them I will bring your greetings and I give you their thanks." (It is of historic interest that the representation from Toronto at this meeting was smaller than expected, because several who had planned to attend remained at home to attend the funeral of the late Sir Frederick J. Banting.)

Dr. George M. Curtis (Fig. 4), secretary through the early years of the society, was indefatigable in his efforts in its behalf. The archives of the society, which it has been my pleasant privilege to review in preparing this address, are filled with letters, correspondence, and notes from and to George Curtis, who must always be considered one of the true fathers of this organization. The accurate records of its early days and the wise counsel which he frequently contributed to the debates and discussions indicate his sincere and effective interest in the ideals of the Central Surgical Association.

World War II brought an abrupt interruption in the activities of the new Association. A letter from George Curtis, the secretary, dated Oct. 19, 1942, reported that a card vote of the entire founders group resulted in an overwhelmingly "No" vote on the advisability of a February, 1943, meeting. This took place at a time when all of the associations were questioning the advisability of meetings, and the Central, being a young men's organization, was even more involved than most by the entry of so many of its members into active military service. The need to cut down the demands for transportation, housing, etc., resulted

eventually in a cancellation of not only the 1943, but also the 1944 and 1945 meetings. The officers of the Association, duly mindful of the need for keeping alive the nucleus of this important enterprise, kept in touch with each other and quietly planned for a resumption of activities at such time as the international situation would permit. The armistice, first with Germany and then with Japan, and the termination of hostilities in 1945 made possible plans for resumption of the meetings and continuing active growth of the society.

The first postwar assembly was held at the Drake Hotel, in Chicago, the formal presentations on Feb. 22 and 23, 1946, being preceded by the invitational clinic programs held at the University of Chicago in the morning and at Northwestern University in the afternoon. The warm hospitality and efficient arrangements of the Chicago members, together with the excellent facilities of that city, have combined to keep the majority of the sessions there, despite repeated plans to alternate years with other cities. Since the war there have been six meetings in Chicago, and one each in Cleveland, Toronto, and Detroit. All have been well attended and highly successful. The local invitational clinics preceding the formal programs have always been very popular, and the plan has been continued with but minor changes.

On two different occasions symposia were presented by invited speakers, and though they were well received, the program committee has always returned to the pattern of a series of 10-minute scientific papers, with the time limitation strictly adhered to.† Fortunately, each year has produced a large number of acceptable papers, which has made the problem of the program committee one of selection rather than one of obtaining suitable material. The more than 90 abstracts submitted for 35 places available this year indicate a continuing interest which augurs well for the quality of future programs.

Perusal of the minutes of the council meetings, a tedious and yet a fascinating experience, reveals many of the problems which have faced this Association. The geographic distribution of the membership has been debated at nearly every council meeting, and on at least two occasions subcommittees have been appointed to consider the problem. Originally there was a preponderance of membership in the states of Michigan, Illinois, and Ohio. This might have been expected because of the medical centers located in these states, and because these were the homes of many who were active in the establishment of the organization. Subsequent years have seen an extension into neighboring states, to the point where the only question which remains is whether the Association is perhaps extending itself somewhat beyond its normal boundaries. The council and committees that have considered this matter have always decided that it would be unwise to set any strict geographical limits, feeling that it would be preferable to let areas of interest and availability of candidates be the deciding factors.

The active membership has been increased from the original 100 to 125, and then to the present limit of 150. The senior membership age was reduced from 55 to 50, in 1949, to provide more places for the younger men, who have always been regarded as the backbone of the society. Recent years have seen a growing reluctance on the part of the council to select men near or past the senior membership age, with an increasing tendency to concentrate on the younger persons for whom the society was originally established. The quality and active participation of our present membership attests to the wisdom of this view.

From time to time considerable debate

† Since delivery of this address, it has been called to my attention that the Central Surgical Association was really a pioneer with respect to the brief presentation of the material, the details being reserved for later publication. This plan proved so successful that a similar policy has since been adopted by other surgical associations.

has arisen as to whether more attention should be given to the selection of members from areas away from the large centers. Each year an attempt has been made to include persons from these smaller communities, and there can be no doubt that such men are stimulated and their ideals sustained by such support from the society. On the other hand, it is perfectly obvious that the opportunities for producing scientific papers, be they clinical or based upon fundamental research, are far greater in the larger centers, and particularly in those with university and medical school associations. Since the very life of the society depends upon a continuing supply of suitable papers, it is inevitable that the membership must continue to be preponderantly chosen from the centers where such opportunities exist, though the smaller communities should not be neglected.

Each year has seen the number of guests increasing to a point where attendance by guests now usually exceeds that by members. In 1941, there were 80 members and 31 guests; in 1955, there were 189 members and 244 guests. Mindful of the value which guests receive from the meetings and of the tribute which their attendance pays to the association and to the excellence of its programs, the council has always felt that no attempt should be made to limit their numbers.

Publication of the papers and proceedings of the meetings has been a recurrent problem to the council. The first group of papers was published in brief form in the *Annals of Surgery*, and was welcomed by that journal. However, this abstract form was too brief and sometimes blocked publication of the complete paper elsewhere. Papers from the second and third annual sessions were published in *Surgery*, some of them in complete form, the remainder in abstract. The ARCHIVES OF SURGERY published the papers from the fourth and all subsequent meetings. An arrangement has finally evolved whereby this journal assumes responsibility for publishing the papers in groups, within a few months after each meeting. The Association now has a representative on the Board of the A. M. A. ARCHIVES OF SURGERY, and the annual dues include a subscription to that journal. Though many have felt that a published volume of transactions would be desirable, the cost has always deterred the council, and none was ever published.

This concludes a brief review of an enviable record of achievement by the Central Surgical Association, still one of the youngest but already one of the strongest and most active of the regional surgical societies. The organization is now in a most healthy state, firmly established and well-recognized. Mindful of the benefits which its success has assured us, what must be our obligation as to its future?

The emphasis upon youth must surely be continued if the excellence of the programs and what has been referred to as the virility of its proceedings are to be continued. With the number of organizations open to established surgeons and with our free policy with respect to guest attendance, there would appear to be little or no reason for electing older men who are either within or approaching the senior age group. Much strength has been contributed to our programs by the large number of papers given "by invitation." This policy, which contrasts with that of many societies, should be continued and perhaps even increased, for it results in a greater participation of young men and thus often reveals rich sources for additional strength of membership.

The geographical boundaries have never been clearly established, and this appears to be well. A few spots within our normal sphere of activity have been relatively neglected, and these offer possibilities for growth, which might well be cultivated. The Association, however, should never be in the position of competing with other regional societies within their areas. Duplication of effort is already too prevalent among medical societies.

The central location of Chicago has made

it perhaps too often the meeting place. Consideration should be given to a plan of more frequent visits to other areas, particularly those with medical school associations, certainly every other year and perhaps two out of three years. The impositions which our meetings place upon our always cordial and efficient Chicago hosts should not be allowed to occur too frequently. Further, the stimulus offered by visits to new and perhaps unfamiliar centers within our area will enhance our enjoyment of the meetings and further strengthen the standing of the Association.

An interesting addition to our programs might be the utilization of some of our not too limited funds for an annual lectureship. The Association could make a substantial contribution to surgery in its area by inviting an eminent surgeon from another country each year to be a visiting professor for a week at a medical school in the host city and to give an address before the formal meeting of the Association. American surgery and our Association alike would benefit by ties so established with colleagues from other lands.

Finally, our greatest obligation must be to remain steadfast in following the course already so well set by those who guided this organization during its formative years. Your council, by a very real sort of teamplay, has wisely guided the destinies of this Association from its inception to its present position of strength. I am honored that you have allowed me to have some small part in these deliberations, as council member and as President, for I have never failed to be impressed by the conscientiousness and seriousness of purpose which are everywhere apparent in its proceedings. Though the membership of the council changes, year by year, the spirit of the founders continues to pervade its every thought and action. Knowing this, we may rest secure in our confidence that the record of achievement will be equaled and even surpassed in the future course of the Central Surgical Association.

323 E. Chestnut St., Louisville (2).

Alimentary Tract Duplications

W. K. SIEBER, M.D., Pittsburgh

Duplications of the alimentary tract may be defined as those cystic and tubular structures found in relation to normal bowel whose walls resemble intestine and consist of smooth muscle with alimentary tract mucosa. Synonyms for duplication include enterocystoma, enterogenous cyst, enteric cyst, giant diverticulum, ileum duplex, gastroenteric cyst, gastrogenous cyst, and reduplication of the intestine. "Atypical" and "ectopic" Meckel's diverticula are usually duplications. Single reports and reports of small numbers of cases in the literature suggest that duplications occur infrequently. This report concerns 25 cases in which one or more alimentary tract duplications were present.

Material

A total of 25 patients with alimentary tract duplications were seen at the Children's Hospital, of Pittsburgh, from 1934 to 1955. Of these, 3 were Negro and 22 were white. There were 12 male and 13 female patients.

Duplications were discovered or confirmed at surgery in 19 cases.

Duplications were discovered at necropsy in six patients. In three instances (Table 1) it was small and had been asymptomatic. In the remaining three patients of this group, the unrecognized duplication was directly responsible for death. In one child, a 3 cm. cystic duplication situated between the membranous trachea and the esophagus at the level of the thoracic inlet caused choking spells, aspiration pneumonia, and death by respiratory tract obstruction at 2 months of age. In the second patient, a gastric duplication became infected and ruptured, resulting in fatal peritonitis. In the third child, duplication of the colon, appendix, and terminal ileum produced unrelieved intestinal obstruction.

TABLE 1.—*Summary of Findings in Three Asymptomatic Alimentary Tract Duplications Discovered at Autopsy*

No.	Age	Size	Location	Associated Pathology
1	3 days	3 cm. long	Appendix	Congenital heart disease
2	3½ mo.	1 cm. dia.	Ileum	Congenital heart disease; Meckel's diverticulum
3	7 mo.	1 cm. dia. 1 cm. dia.	Stomach Colon	Congenital heart disease; bronchopneumonia

Embryology

Moore and Battersby[1] recognize five groups of duplications: intramural cysts, spherical duplications, tubular duplications, abdominothoracic duplications, and mesenteric cysts with the wall histologically resembling intestine. The duplications reported in this paper were all spherical or tubular.

The origin of duplications remains obscure. At least two major theories are suggested. Simple cysts may be derived from embryological diverticula. Lewis and

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Thyng [2] described diverticula as a constant feature of embryologic development toward the end of the second month in the pig embryo. Bremer [3] suggested that duplications are the result of errors of recanalization. The stomach does not go through a period of occlusion and recanalization of its lumen. Bremer suggests adherence of longitudinal folds as a possible cause of gastric duplications. Moore suggests that gastric mucosa can be aberrant in the same fashion as pancreatic tissue. These theories do not explain the presence of gastric mucosa in or the occurrence of intrathoracic duplications. McLetchie [4] advances a theory that may explain these unusual duplications. He suggests that adhesions of the entoderm to the neuroectoderm produce gastric mucosa within the thorax. Intrathoracic duplications are located in the posterior mediastinum and are often associated with vertebral anomalies. Hemivertebrae were present in three of the five instances of thoracic duplication discussed in this paper.

Clinical Manifestations

The size and location of the duplication determined clinical signs and symptoms. Four intrathoracic duplications caused recurrent pneumonia. Vomiting and dysphagia were present in one child. Inadequate weight gain, anorexia, and unexplained fever occurred in three cases. In four patients, roentgen examination of the chest suggested the proper diagnosis. The smooth, rounded posterior mediastinal shadow of water density usually extending into the right hemithorax was characteristic in children.

Abdominal duplications caused intestinal obstruction, bleeding, or both. A single massive rectal hemorrhage was the only symptom in one child with duplication of the jejunum. Melena occurred in six other cases, but was not the presenting symptom. Bleeding or melena may occur from aberrant gastric mucosa, from pressure of a spherical mass, or from secondary intussusception.

Fourteen patients presented with intestinal obstruction. Impingement from without by the cyst on the intestinal lumen caused obstruction in nine; obstruction was present at birth in two of these cases. Intussusception with the duplication as a lead point caused obstruction in three children. Multiple duplications of the ileum were responsible for volvulus and obstruction in one child. In one newborn infant, complete intestinal obstruction was due to ileal atresia. A large ileal duplication distal to the atresia was an incidental finding at operation.

The duplication was palpable in 10 patients. In one, an abdominal mass rapidly increasing in size was the only symptom.

Roentgen examination was of limited value in identifying abdominal duplications. In three instances, a mass of water density displaced the abdominal viscera. The roentgen study did disclose the presence of intestinal obstruction and helped identify its site. The combination of a palpable mass with intestinal obstruction makes preoperative recognition possible. The preoperative diagnosis of abdominal intestinal duplication was correctly made in six patients in this series.

Pathology

Duplications occurred singly within the thorax in five patients. A total of 28 duplications in 20 patients were within the abdomen.

Four of the five intrathoracic duplications originated from the posterior mediastinum and extended into the right hemithorax. All five were intimately related to the esophagus. All were cystic and spherical. Clear, thin, yellow fluid filled three of the cysts; in two, the fluid was thick and chocolate-like with the lining mucosa ragged and ulcerated. Rapid contraction of the cyst occurred after aspiration of its contents in each instance. There were extensive fibrosis, necrosis, and calcification in one cyst wall. The cyst walls varied in thickness from 3 to 8 mm. Lining mucosa was squamous epithelium in one, columnar in another,

cuboidal in a third, and gastric in two.

Four abdominal duplications were tubular, and three communicated at one end with the normal intestinal lumen. One tubular duplication extending along the base of the mesentery from the greater curvature of the stomach to the ileocecal area did not communicate with the intestinal lumen. Twenty-four were spherical, cystic, and without communication with the adjacent bowel.

Of the abdominal duplications, 5 were attached to the stomach along its greater curvature, 19 to the small intestine sharing a common mesenteric blood supply, and 1 to the colon. Of the remaining two, one lay along the base of the small bowel mesentery and the other was retroperitoneal.

Mucous membrane lined the interior of all abdominal duplications. Necrosis of the epithelial lining was present in one. Well-differentiated serosa, muscularis, and submucosa comprised the rest of the wall. The lining mucosa was usually identical with that of the adjacent viscus. Gastric mucosa was found in the tubular jejunal duplication, combinations of colonic and ileal mucosa in three ileal-cecal duplications, and colonic epithelium in the retroperitoneal duplication. The cysts contained clear fluid of varying consistency. In two instances, thick chocolate-colored fluid was present.

Multiple duplications were present in four patients (see Tables 1 and 3). One patient had five separate duplications; a second child had three. Two children each had two separate duplications.

Associated congenital anomalies were present in nine patients. These anomalies included congenital heart disease, hemivertebrae, intestinal malrotation, Meckel's diverticulum, ileal atresia, skeletal anomalies, and double bladder.

Treatment

The treatment of duplications is surgical; excision is carried out where possible. Nineteen patients were treated surgically.

An intrathoracic duplication was removed in four patients. These duplications were located close to, but did not communicate with and were not intimately attached to, the esophagus. Dissection was tedious. The fluid was aspirated to reduce the size and allow manipulation in one large duplication. All four of these patients are living and well. The postoperative course was stormy in two children who were in poor preoperative condition.

Fifteen patients with abdominal duplications were operated upon and the lesion excised, with one death. Follow-up in this group extends from 5 months to 10 years. The mortality occurred in a 3-month-old infant five days following reduction of an ileoileal intussusception and resection of an ileal duplication in 1934. Resection of adjacent intestine was necessary in removing abdominal duplications located near the intestine. Two duplications, however, were located in such a way that they could be removed without disturbing surrounding viscera.

Report of Cases

The following case reports are typical of the clinical problems presented by patients with duplications.

CASE 1.—A 4-month-old white boy was admitted because of failure to gain weight, constant dyspnea with repeated respiratory infections, and anorexia. The infant was one of twins, the female sibling being well. On physical examination, there was marked pectus excavatum, respiratory rate constantly in excess of 60 a minute, and temperature elevation to 101 F daily. The abdomen was prominent, and there was marked thoracic scoliosis. Roentgen examination of the chest showed thoracic hemivertebrae, scoliosis, and a large, smooth rounded shadow of water density in the right hemithorax. The shadow arose from the posterior mediastinum (Fig. 1). After waiting two months for the infant's general condition to improve, the child was operated upon. On Nov. 23, 1953, a right thoracotomy was performed. A dense, white, thick-walled mass arising from the posterior mediastinum filled the right lower hemithorax compressing the right lung into the right upper chest. The mass was made smaller by aspirating 200 cc. of thin yellow fluid. The cyst was then easily removed. The postoperative course was uneventful. Symptomatic improvement was

TABLE 2.—*Summary of Findings in Five Intrathoracic Alimentary Tract Duplications*

No.	Sex	Age	Site	Size	Symptoms	Treatment	Lining Mucosa and Wall	Result
1	F	Birth	Thoracic inlet between trachea and esophagus	3 cm. dia.	Stridor, Pneumonia	None	Squamous epithelium	Died 1934; autopsy; age 2 mo.
2	M	6 wk.	Right-posterior mediastinum	4.5 cm. dia.	Pneumonia, cyanotic spells, poor weight gain, fever	Excision 3-17-50; age 2 ½ mo.	Cuboidal epithelium intestinal glands; extensive necrosis and calcification, wall 4 to 4 mm. thick.	Living and well 5 yr. Po.
3	M	11 mo.	Right-posterior mediastinum	6.5×4.5×3.5 cm., "pear shaped"	None	Excision 10-12-52	Columnar epithelium; 2 to 4 mm. thick	Living and well 3 yr. Po.
4	M	4 mo.	Right-posterior mediastinum	4 cm. dia.	Pneumonia, vomiting, dysphagia, fever, anorexia	Excision 11-23-53	Gastric and squamous epithelium; necrosis, wall 8 mm. thick	Living and well 2 yr. Po.
5	M	4 mo.	Right-posterior mediastinum	4 cm. dia.	Pneumonia, poor weight gain, fever	Excision 11-12-55	Gastric mucosa, 5 mm. thick wall	Postoperative chylothorax, now living and well 3 mo. Po.

TABLE 3.—*Summary of Findings in Seventeen Abdominal Alimentary Tract Duplications*

No.	Sex	Age	Location	Size	Symptoms	Treatment	Lining	Result	Associated Pathology
1*	M	2 mo.	Stomach, 2 Duodenal, 2 Ileal, 1	(A) 5 cm. (B) 3 cm. (C) 3 cm. (D) 2 cm. (E) 1 cm.	Obstruction, malnutrition, abdominal masses, melena	None	(A) Gastric (B) Gastric (C) Intestinal (D) Intestinal (E) Intestinal	Died 1948, peritonitis from rupture of gastric duplication	
2*	F	1 mo.	Stomach	(A) 4×3×3 cm. (B) 2½×1½ cm.	Obstruction, abdominal mass	Excision 4-24-54	Gastric	Living and well	
3	M	5 mo.	Jejunal	20 cm.	Rectal hemorrhage	Excision 10-15-53 and anastomosis	Intestinal and gastric	Living and well	Thoracic hemivertebrae
4	F	4 mo.	Ileum	3 cm. dia.	Intussusception, abdominal mass	Excision 11-3-34 and anastomosis	Intestinal	Died 11-4-34	
5	F	13 yr.	Ileum, 3	(A) 12× 5×4 cm. (B) 9×5×4 cm. (C) 4×4×4 cm.	Obstruction, vovulus, abdominal mass, melena	Excision and anastomosis 9-3-45	Intestinal	Living and well	
6	F	2 mo.	Ileum	8×7×3½ cm.	Obstruction, abdominal mass	Excision and anastomosis 11-27-49	Intestinal	Living and well	
7	F	4 mo.	Ileum	1.2 cm.	Intussusception	Reduction of Intussusception 8-18-50; excision and anastomosis 9-9-50	Intestinal	Living and well	
8	F	2 yr.	Ileum	2 cm. dia.	Obstruction	Excision and anastomosis 10-10-50	Intestinal	Living and well	

TABLE 3.—*Summary of Findings in Seventeen Abdominal Alimentary Tract Duplications*—Continued

No.	Sex	Age	Location	Size	Symptoms	Treatment	Lining	Result	Associated Pathology
9	F	1 day	Ileum	5×4×3 cm.	Obstruction	Excision and anastomosis 8-5-52	Intestinal	Living and well	Ileal atresia and meconium peritonitis
10	M	7 days	Ileum	4 cm.	Obstruction, melena, abdominal mass	Excision and anastomosis 10-12-53; closure jejunum and ileocolostomy 10-19-53	Intestinal	Living and well	
11	M	4 days	Ileocecal	2 cm.	Obstruction	Excision and anastomosis 11-22-51	Colon	Living and well	
12	M	21 mo.	Ileocecal	5 cm.	Intussusception, abdominal mass	Barium enema reduction and excision 8-16-53	Intestinal and colon	Living and well	
13	M	2 wk.	Ileocecal	2.5 cm.	Bloody diarrhea, abdominal mass	Excision and anastomosis 4-21-55	Colon and intestinal	Living and well	
14	F	11 mo.	Ileocecal	2 cm.	Obstruction	Excision and anastomosis 6-26-55	Intestinal and colonic	Living and well	
15	M	3 mo.	Retroperitoneal	8 cm. dia.	Mass left flank increasing in size	Excision 5-17-50	Necrotic colonic (?)	Living and well	
16	F	2 wk.	Colon	17×4 to 6 cm.	Obstruction epigastric mass	Exploratory lap. 9-1-43; marsupialization 11-12-43; excision 7-16-48	Colonic	Living and well	
17*	M	8 mo.	Colon and appendix	Entire colon	Obstruction	None	Colon appendix	Died 1944	Intestinal malrotation, double bladder

* Cases previously reported from this hospital, References 6 and 7.

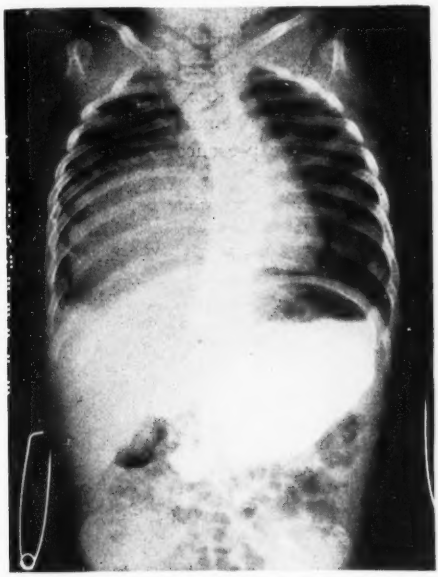

Fig. 1 (Case 1).—Roentgenogram of the chest. There are scoliosis and thoracic hemivertebrae. A smooth rounded shadow of water density fills the inferior half of the right hemithorax.

immediate. This child has been well for the two years he has been followed.

The cyst measured 4 cm. in diameter (Fig. 2). Its wall was lined with gastric mucosa.

Comment.—This patient was observed for two months and through two hospital admissions. His clinical condition did not improve until the cyst was removed. Prompt removal of an intrathoracic duplication is indicated even when mechanical displacement of viscera does not appear to cause symptoms. Many thoracic duplications contain gastric mucosa, and the mucosal ulceration may be responsible for such later serious complications as perforation. Absorption from an ulcerated surface may be sufficient to cause constitutional symptoms.

CASE 2.—A 5-month-old white infant was admitted to the hospital because of massive rectal hemorrhage one week prior to admission. Transfusion of 500 cc. of whole blood was necessary to restore the hemoglobin from 3 gm. to 8 gm. per 100 cc. The infant continued to have melena. At operation, Nov. 15, 1953, a 20 cm. long tubular duplication was found on the mesenteric side of the distal jejunum (Fig. 3). The structure communicated with the jejunum distally. Resection

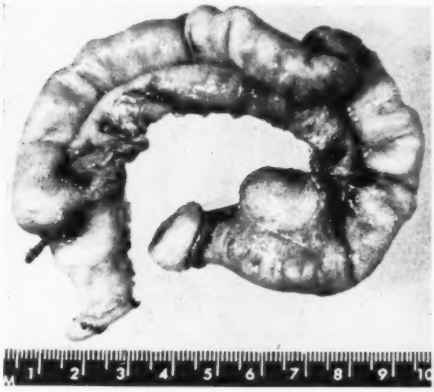

Fig. 3 (Case 2).—Gross specimen. The duplication lies within the mesentery of normal intestine, sharing its blood supply. Resection of adjacent intestine was necessary. The communication with normal intestine is distal. Gastric mucosa lined the duplication.

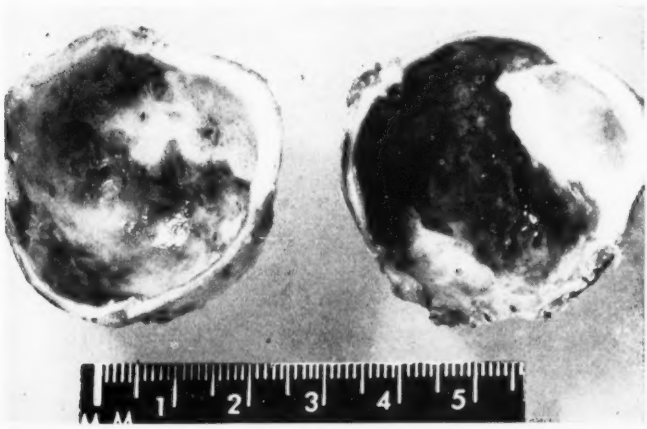

Fig. 2 (Case 1).—Gross specimen. The cyst measured 4 cm. in diameter, and its wall, 8 mm. in thickness. The lining gastric mucosa shows extensive ulceration.

of the adjacent jejunum with the duplication was necessary. The infant's postoperative course was uneventful, and this child is completely well three years postoperatively.

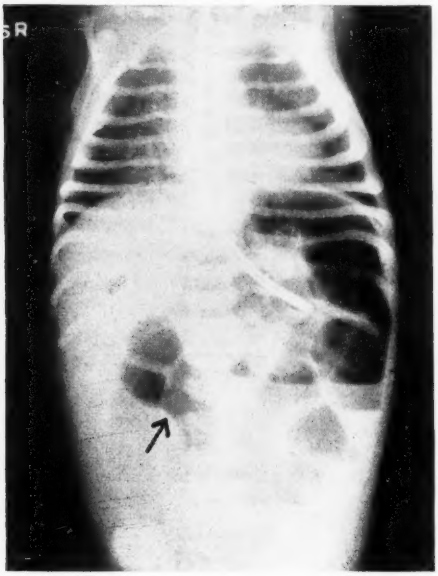

Fig. 4 (Case 3).—Roentgenogram of abdomen. There are roentgen signs of intestinal obstruction. The arrow is directed at the site of impingement of the duplication on adjacent bowel. This mass was palpable.

Comment.—The management of massive intestinal hemorrhage in infants and children has been a controversial problem. Should such patients have an exploratory laparotomy during that hospital admission or should one wait for the second episode of bleeding? Continuing melena after an initial massive hemorrhage is clearly an indication for exploration as in this patient. Massive intestinal hemorrhage may be the only sign of the presence of an abdominal duplication.

Case 3.—A 7-day-old white boy was admitted to the hospital Oct. 12, 1953, because of persistent bilious vomiting with progressive abdominal dis-

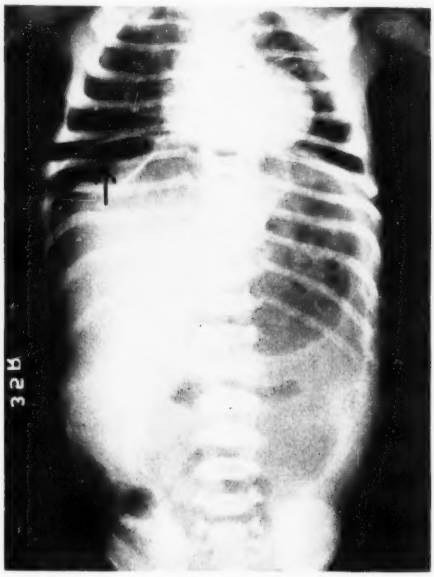

Fig. 6 (Case 3).—Roentgenogram of abdomen shows free air and fluid within the peritoneal cavity, following rupture of intestine proximal to the anastomosis.

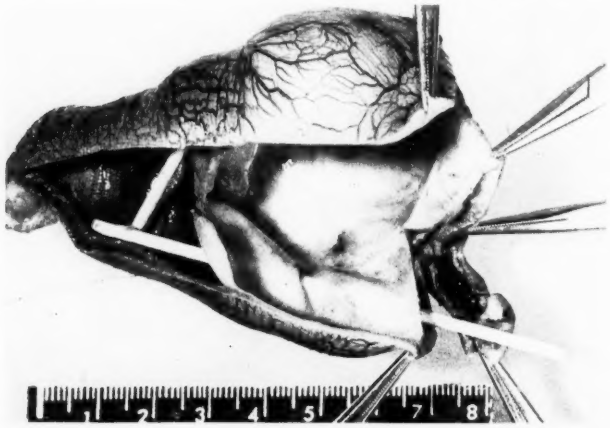

Fig. 5 (Case 3).—Gross specimen. The tense, thin-walled cyst had compressed the lumen of the ileum. A wooden probe placed within it demonstrates this lumen. The vertically placed smaller probe demonstrates the lumen of the dilated proximal ileum.

tention since 2 days of age. The infant had passed transition maroon-colored stools. The temperature was 105 F, the abdomen greatly distended, and an egg-sized right lower quadrant abdominal mass was palpable (Fig. 4). There was dark blood in the rectum. Following preoperative preparation the baby was operated upon. An ileal duplication, 3 cm. in diameter, was resected (Fig. 5), and an end-to-end ileoileostomy was done 3 cm. proximal to the ileocecal valve. Suturing repaired serosal tears in the proximal dilated intestine. The postoperative course was uneventful until the seventh postoperative day, when sudden abdominal distention occurred. Roentgenograms showed pneumoperitoneum (Fig. 6). The infant was operated upon; complete separation of a loop of jejunum with generalized peritonitis was found. Intestinal continuity was restored by end-to-end jejunal anastomosis. The terminal ileum proximal to the previous anastomosis was then anastomosed to the cecum in side-to-side fashion. The infant made an uneventful recovery and was discharged after three weeks of total hospitalization. This child is developing normally and was physically and mentally well two years later.

Comment.—In this patient, diagnosis was delayed by the partial nature of the intestinal obstruction. Two matters of surgical technique deserve comment. Prolonged distention of this infant's intestine had caused serosal tears, complicating the first operation. It was necessary to reinforce the intestinal wall at these sites. The second comment concerns the advisability of ileocolostomy rather than ileoileostomy in surgical relief of obstructing lesions near the terminal ileum in newborn infants. Ileocolostomy provides more rapid and safer decompression. This procedure has been recommended and the details described by Benson.[8]

CASE 4.—A 21-month-old boy was admitted to the hospital on Aug. 16, 1953, because of cramping abdominal pain and bloody diarrhea of six hours' duration. A large tender mass was palpable in the right upper quadrant of the abdomen. A diagnosis of ileocolic intussusception was made. Reduction was easily effected by hydrostatic pressure (Fig. 7). Following the reduction, however, a nontender abdominal mass persisted in the right lower quadrant. The roentgenologist demonstrated a persistent, nonobstructing mass in the area of the terminal ileum (Fig. 8)., The patient was, however, completely relieved of symptoms. Twelve hours following reduction, a laparotomy was performed and a 5 cm. in diameter ileocecal duplica-

Fig. 7 (Case 4).—Roentgenogram of abdomen. The filling defect characteristic of intussusception and the dilated proximal small intestine are shown.

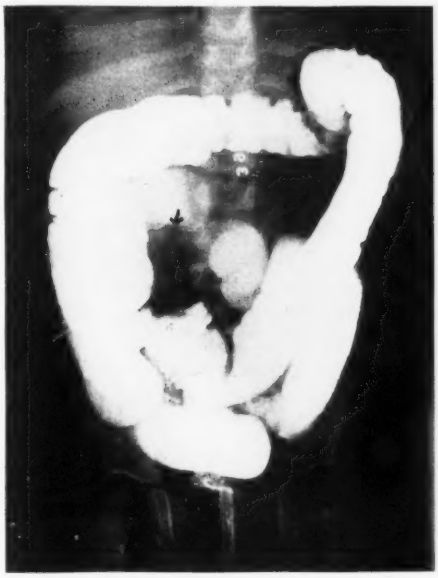

Fig. 8 (Case 4).—Roentgenogram of abdomen. The rounded shadow of water density is well visualized displacing surrounding loops of barium-filled intestine. There is no evidence of obstruction and the intussusception has been completely reduced.

Fig. 9 (Case 4).—Gross specimen. The ileocecal region is distorted by a nonobstructing intramural cyst.

tion was removed (Fig. 9). Convalescence was uneventful. This patient has developed normally and was in excellent health two and one-half years later.

Comment.—Hydrostatic pressure was used to reduce the intussusception. In the present wave of enthusiasm for hydrostatic pressure reduction of intussusception, the possibility of a lead point being present should not be forgotten. This lesion was recognized by a radiologist experienced in this procedure and alert to the limitations of the method.

The 12-hour delay in resection of the duplication was due to the parents' initial refusal to permit operation.

Summary and Conclusions

Twenty-five patients with alimentary tract duplications are reported; in six the duplications were found at autopsy and in nineteen at surgery.

Four duplications within the thorax produced pneumonia, poor weight gain, and anorexia.

Fifteen abdominal duplications caused intestinal obstruction, bleeding, or both.

The origin of duplications is uncertain.

Treatment of this condition is surgical. Eighteen of nineteen patients operated on are alive and well today.

These patients were operated upon by the members of the surgical staff of the Children's Hospital, of Pittsburgh. Drs. D. Clare, G. V. Foster, E. M. Kent, W. B. Kiesewetter, E. S. A. King, J. J. McAleese, and T. N. Merideth granted permission to include their cases in this review.

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The Surgical Complications of Meckel's Diverticulum in Infants and Children

An Analysis of Sixty Cases

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and
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A Meckel's diverticulum or remnant of the vitelline duct is said to be present in about 2% of all postmortem examinations.* Although many persons live their normal span of life asymptomatically despite this anomaly, we have been impressed that its presence may be made known dramatically by its initiating serious surgical complications in the pediatric age group. In this report we have reviewed the records of 60 patients in the pediatric age group who demonstrated surgical complications of this lesion. None of the patients whose Meckel's diverticulum was discovered as an incidental finding at laparotomy for other lesions † are included in this paper.

Age Incidence

The ages covered range from 1 day to 14 years, and it is noted that 27, or 45%, of the patients were in the newborn or infant group, and 45, or 75%, of the patients were 5 years or younger (Fig. 1). Further analysis reveals that the largest single age group represented was from one day to one year of age, or 32% of the total series of 60 patients.

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From the Surgical Service of the Children's Hospital of Michigan, Harper Hospital, and Wayne University College of Medicine, Detroit.

* References 5, 10, and 20.

† References 3 and 10.

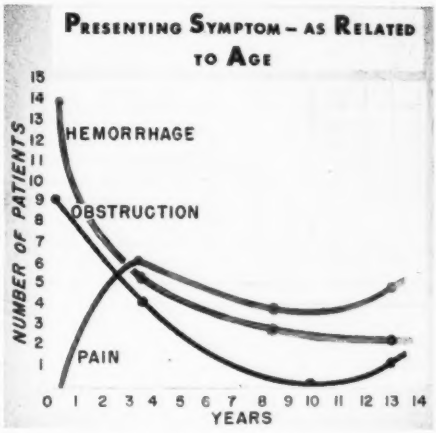

Fig. 1.—Graph showing incidence of surgical complications in the various age groups.

TABLE 1.—*Age Incidence*
Ages Covered—0 to 14 Yr.

Age	No. of Patients	
0- 4 mo.	6	27 (Infant group)
5- 8 mo.	7	
9-12 mo.	6	
13-24 mo.	8	
2 yr.	5	18
3 yr.	1	
4 yr.	5	
5 yr.	7	
6 yr.	1	15
7 yr.	0	
8 yr.	1	
9 yr.	3	
10 yr.	2	
11 yr.	4	
12 yr.	0	
13 yr.	1	
14 yr.	3	
	Total 60	

Complications Demanding Surgery

Intestinal Hemorrhage.—This was the commonest indication demanding surgical intervention. A total of 24 patients, or 40%

TABLE 2.—*Indications for Surgery*

	Complications	No. of Patients
1	Hemorrhage	24
	Moderate to severe	20
	Mild	4
2	Pain, simulating appendicitis	15
3	Intestinal obstruction	14
	Intussusception (inversion of Meckel's into lumen of bowel)	9
	Bands and torsion	5
4	Umbilical discharge	4
5	Perforated Meckel's with peritonitis	3
		Total 60

of all our patients, had this complication, and 14 patients of this group were one year of age or younger. The degree of blood loss was classified as moderate to severe in 20, and mild or recurrent in 4.

Of the 24 patients who had intestinal hemorrhage, 23, or 96%, had ectopic mucosa in the Meckel's diverticulum. In all cases the ectopic mucosa was gastric, except in two instances where there was an associated area of pancreatic tissue. These data support the opinion, expressed by Berman, Schneider, and Potts,[2] that "if numerous microscopic sections are studied, resected diverticula that have bled will show gastric mucosa in nearly 100% of cases." It is of interest to note that in one patient duodenal mucosa was found in an inflamed diverticulum, but this patient did not have hemorrhage.

TABLE 3.—*Indications for Surgery in the Infant Group*

Age 0-24 Months—27 Patients

Complications	No. of Patients
Hemorrhage	14 (52%)
Obstruction	
Intussusception	5
Bands, torsion	4
Fistula	3
Perforation	1

Abdominal Pain.—There were 15 patients in this group, or 25% of the series. In all 15 patients the preoperative diagnosis was acute appendicitis. However, it must be noted that the location of pain was variable, periumbilical, right lower quadrant, and occasionally left lower quadrant. In all cases, the microscopic findings were those of an acute diverticulitis. In all patients, the presenting symptoms of pain were eliminated by the surgical removal of the inflamed Meckel's diverticulum.

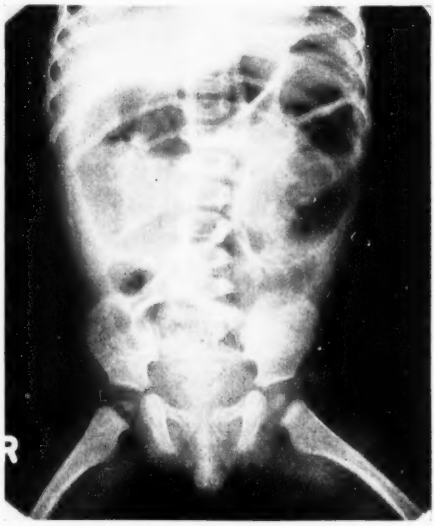

Fig. 2.—Scout film showing marked obstruction of the terminal ileum and jejunum.

Intestinal Obstruction.—Acute intestinal obstruction occurred in 14 patients, or 23%. In nine, the acute obstruction was the result of the inversion of the Meckel's diverticulum into the lumen of the ileum (Figs. 2, 3, and 4).

The intestinal obstruction in the other four patients was the result of a volvulus of the closed loop-type or a strangulation of a loop of bowel around the fibrous cord-like remnant of the vitelline duct. This cord-

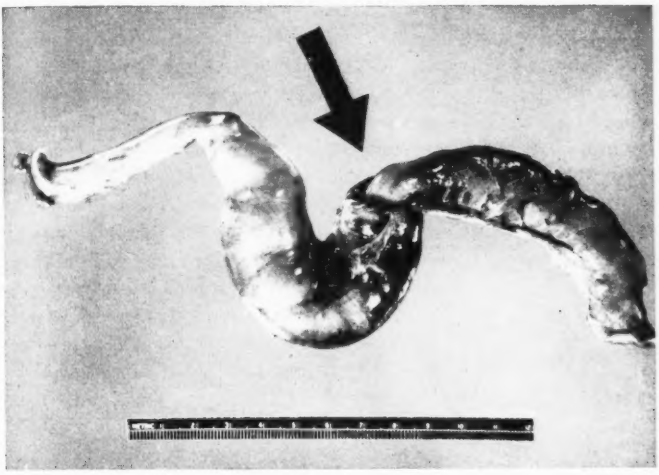

Fig. 3.—Resected specimen of irreducible ileo-ileal intussusception due to an inverted Meckel's diverticulum.

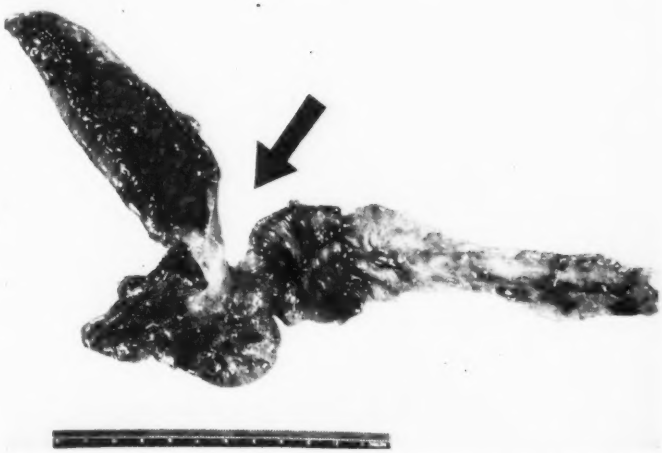

Fig. 4.—Opened specimen with arrow pointing to gangrenous Meckel's diverticulum with thickened base.

like structure was found attached to the anterior abdominal wall, a segment of bowel, or the parietal peritoneum. In this series of acute intestinal obstruction, nine patients were 1 year of age or younger, four were between 2 and 5 years of age, and a single patient with obstruction was 13 years old. This emphasizes that invariably acute intestinal obstruction secondary to a Meckel's diverticulum, or its remnant, is most frequently a complication in infancy and the early childhood period.

Perforation and Peritonitis.—Three patients, or 5%, are included in this group, the age being 5 days, 3 years, and 5 years, respectively. Perforation of a Meckel's diverticulum represents a grave surgical complication. The location of a Meckel's diverticulum lying free in the peritoneal cavity hinders the natural body defenses in

TABLE 4.—*Ectopic Mucosa in Meckel's Diverticulum*

Tissue	No. of Patients
Gastric	25 (Hemorrhage, 21)
Gastric+pancreatic	4 (Hemorrhage, 2)
Pancreatic	1
Duodenal	1
	Total 31 (52%)

walling off such a lesion. In addition, the fluid consistency and high digestive quality of the ileal contents produce a severe peritonitis.[6]

Fistula.—In the remaining group of four patients, the presenting symptom was drainage of a serous to brown or hemorrhagic fluid from the umbilicus. Drainage usually began after birth with the spontaneous separation of the umbilical stump and persisted until the time of surgery.

TABLE 5.—*Presenting Symptom as Related to Age*

Symptom	Age, in Yr.	No. of Patients	
Hemorrhage	0- 1	14	
	2- 5	5	
	6-10	3	
	11-14	2	
		24	(40%)
Pain	0- 1	0	
	2- 5	6	
	6-10	4	
	11-14	5	
		15	(25%)
Obstruction	0- 1	9	
	2- 5	4	
	6-10	0	
	11-14	1	
		14	(23%)
Perforation, peritonitis	0- 1	1	
	2- 5	2	
		3	(5%)
Fistula	0- 1	3	
	2- 5	1	
		4	(7%)

Excision of the patent vitelline duct brought prompt remission of drainage and primary healing.

Surgical Management

In the surgical management of patients in the pediatric age group, who develop these serious complications of Meckel's diverticulum, it is highly essential that the needs of the patient as to fluid and blood replacement be individualized in the preoperative, operative, and postoperative period to minimize morbidity and mortality.

In those patients whose presenting symptom is hemorrhage of moderate to severe degree with occasional hemorrhagic shock, we believe that blood replacement sufficient to bring the hemoglobin level to 9 or 10 gm. preoperatively is mandatory for the successful outcome of the contemplated surgery. We have never regretted taking the necessary time (usually 6 to 12 hours) to properly prepare these patients for surgery, and we do not subscribe to the idea of immediate surgical intervention. By elevating the hemoglobin to a satisfactory level we accomplish these things: First, and very important, there is sufficient circulating hemoglobin to meet the oxygen demands of the patient, thereby eliminating anoxemia during anesthesia. Second, operative shock, especially in those patients needing intestinal resection, is practically eliminated. Third, the patient is converted from a poor to a good risk for surgery. In the 24 patients in whom hemorrhage was the presenting symptom, the above blood replacement was carried out and as a result there was no mortality.

In all patients presenting with intestinal obstruction, a Levin tube with suction is instituted on admission. A number of hours are spent in partially correcting their fluid and electrolyte imbalance preoperatively in order to make them better operative risks. Since microchemical evaluation of electrolytes is available in our institutions, their use not only has served as a guide to preoperative fluid therapy but has been of inestimable value in determining the type of fluid replacement necessary in the postoperative period. In the obstructive group, when there is marked distention of the proximal intestinal segment, intestinal decompression by suction at the time of laparotomy is essential before proceeding with intestinal resection and anastomosis or diverticulectomy. Decompression of the proximal intestinal segment serves, first, to rid the bowel of all fluid and gas and, second, to restore an otherwise compromised circulation. The

decompression also serves to eliminate the disparity between two segments of bowel when anastomosis proves necessary. In addition, adequate decompression not only serves to protect the suture line in the postoperative period, but allows for easy closure of the abdominal incision.

As to specific surgical procedures carried out in these 60 patients, 42, or 70%, had a diverticulectomy performed. The remaining 18, or 30%, needed resection of the diverticulum and a portion of the attached ileum.

TABLE 6.—*Surgical Treatment*

Surgical Procedure	No. of Patients	Type of Anastomosis	
Meckel's diverticulectomy	42 (70%)		
Resection of Meckel's and attached ileum	18 (30%)	End-to-end	16
		End-to-side ileocolostomy	1
		Side-to-side ileocolostomy	1
Total	60		

The indications for ileal resection were as follows: (1) wide base in which simple closure would compromise the ileal lumen; (2) irreducible ileoileal intussusception due to inverted Meckel's diverticulum; (3) volvulus with gangrenous intestine, and (4) marked thickening of base of Meckel's diverticulum due to ectopic tissue. As to the type of anastomosis performed after resection in the 18 cases, 16 had end-to-end, 1 side-to-side, and 1 end-to-side ileocolostomy. In all of our cases, an open, two-layer anastomosis was performed, with use of fine interrupted sutures.

Results and Comment

A total of 60 infants and children with complications of Meckel's diverticulum or vitelline duct remnant were operated upon with 4 deaths, or a mortality rate of 6.7%.

Of the four patients who died, three were newborns, two of whom were premature. All had acute intestinal obstruction due to volvulus with gangrenous bowel. The other infant who died was a 5-month-old boy who was admitted after a three-day period of acute intestinal obstruction. At laparotomy, extensive gangrenous small bowel was found, resection was carried out, but the patient died the day following surgery.

TABLE 7.—*Operative Results*

Recoveries	56
Deaths	4
Total	60
Mortality	6.7%

It has been stated by Owen and Finney[14] that the surgical treatment of an uncomplicated Meckel's diverticulum is attended with an over-all mortality of 3% to 5%. Chaffin,[4] in 1941, reported from the Children's Hospital of Los Angeles that 7 out of 19 patients operated upon for complications of Meckel's diverticulum failed to survive, a mortality of 37%. Gross [8] reported their experience of 76 patients operated upon from 1940 to 1950, in which there were 5 deaths, in contrast to 16 deaths in 73 patients operated on up to 1940. Aitken [1] reported 88 cases in infants and children; of these, 73 had definite lesions involving vitelline duct remnants, while the remaining 15 were found as incidental lesions during laparotomy. Of the 88 cases, there was an over-all mortality of 17%. Of the pathological cases (73 cases), the mortality rate was 20.5%. It was found in their series that of the 15 deaths 12 occurred in patients 5 years or younger, and 6 of these 12 occurred during the first year of life, which emphasizes the lethal nature of this lesion in infancy.

Summary and Conclusions

The records of 60 infants and children who presented surgical complications of a Meckel's diverticulum or vitelline duct remnant are reviewed.

The complications encountered in this group in order of their frequency were in-

testinal hemorrhage, abdominal pain, acute intestinal obstruction, umbilical fistula, and perforation with peritonitis.

In the pediatric age group and especially in the newborn and infant, the judicious use of parenteral fluid and blood in the management of these complications is mandatory for a good survival rate.

In those patients who have had moderate to severe intestinal hemorrhage, we believe it highly essential to restore the blood volume to near normal levels before attempting surgical intervention. Because we adhered to this regimen in our 24 patients who had intestinal hemorrhage, all survived.

From this study it is apparent that the surgical complications of Meckel's diverticulum or vitelline duct remnant are most frequently mechanical obstruction or intestinal hemorrhage in the first two years of life (38% in this series). In contrast, with increasing age above the infant group, intestinal hemorrhage and obstruction are less frequent, but acute inflammation of the Meckel's diverticulum is more frequent.

Of the 60 infants and children operated upon, there were 4 deaths, or a mortality rate of 6.7%.

Of the four patients who died, all had acute intestinal obstruction and gangrenous bowel.

Of the 18 patients who required intestinal resection and anastomosis, 15 survived.

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Further Studies in Intussusception in Infants and Children

A Report of Fifty-Eight Cases Treated From 1946-1955

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In 1947 we reported a consecutive series of 99 intussusception cases in infants and children from the Cook County Children's Hospital, covering a 21-year-period from 1925 to 1946. There was an over-all mortality of 19.1%. In the last 45 cases of this series, between 1941 and 1946, the mortality was 6.6%. Since this time another 10 years of experience with this disease has accumulated in this institution, and during this period 58 additional cases of intussusception have been encountered and treated. There were no mortalities among these patients. Two infants were admitted in extremis and died before treatment could be undertaken. These two cases are excluded from our present series (Table 1).

TABLE 1.—*Intussusception in Infants and Adults, Cook County Children's Hospital*

Year	Cases	Mortality
1925-1931	13	53.8%
1932-1938	18	16.6%
1939-1945	68	13.2%
Total	99	19.1%
1946-1955	58	0.0%
Totals 1925-1955	157	8.2%

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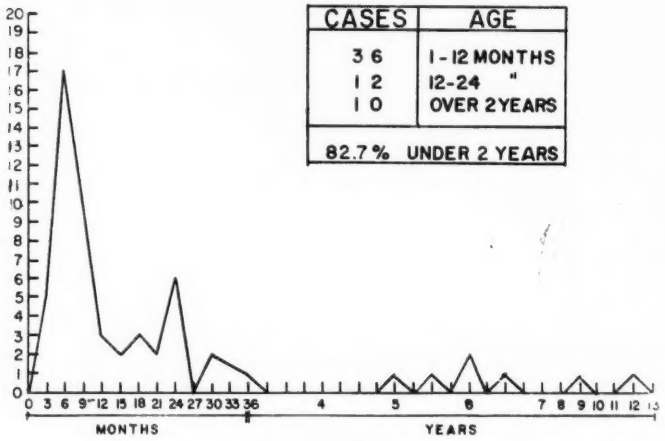
In this series the pattern of age and sex incidence and frequency of the disease showed no significant change from that reported in the earlier series nor from that generally accepted. Of the 58 patients, 36 were 1 year or younger and 12 patients were between 1 and 2 years of age. This group comprised 82.7% of the total. The remaining 11 were over 2 years of age, the eldest patient being 12 years of age.

Boys numerically predominated over girls by a slightly narrower margin than usual, 35 to 23, and the distribution of race was 46 Negro to 12 white. Among Negroes, there were 28 boys to 18 girls, and white boys outnumbered the girls 7 to 5. This racial distribution is consistent with the present census of the Cook County Children's Hospital. This incidence of the disease occurred in 68,287 admissions, or 1 to every 1175.

Previous reports, including our own, have made rather exhaustive studies and comparisons of the age, sex, etiology, and symptom picture of intussusception; hence, it is not the purpose of this communication to enlarge further on that phase of the problem, but rather to enumerate our findings and to draw attention to various factors which have been so important in lowering the mortality in this disease (Charts 1 and 2).

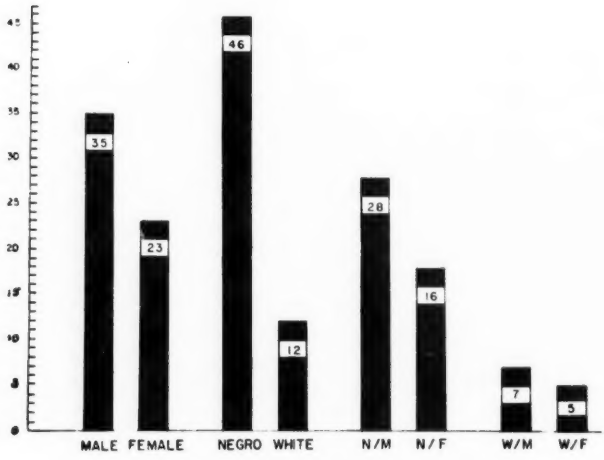
Etiology

Causative factors for intussusception were found in five cases (8.6%), and conditions which might be considered predisposing or relative factors in another four (6.9%) (Table 2). Most authorities agree that enlarged mesenteric lymph nodes are not to be considered as causative factors in



AGE INCIDENCE

Chart 1



SEX AND RACE INCIDENCE

Chart 2

intussusception. The frequency of their presence in any infant or child, with the slightest illness, is well recognized by the experienced surgeon; hence, on a proportion basis there is no relationship. Mesenteric gland enlargement was observed, however, to be present in 14 of our 47 cases operated on. In no instance were they interpreted as being causative.

The predisposing or relative etiologic factors which were noted in the four cases were pinworms in one infant and amebiasis in another. These parasitic infestations were discovered in both instances postoperatively, and we believe that abnormality of peristalsis caused by them could have been the cause, or their presence could have been coincidental.

TABLE 2.—*Data on Causative and Predisposing Factors*

Etiology	No. of Cases	Ages
Causative factors		
Intestinal polyps	3	6 yr., 6 yr., 6 mo.
Congenital ileocecal band	1	3 mo.
Meckel's diverticulum	1	3 mo.
Total	5 (8.6%)	
Predisposing factors		
Amebiasis	1	6 mo.
Pinworm	1	20 mo.
Purpura	2	24 and 30 mo.
Total	4 (6.9%)	

Interestingly, the other two cases were associated with purpura. The differential diagnosis of anaphylactic or Schönlein-Henoch's purpura and intussusception has always been recognized as being quite difficult. The first record of their coexistence successfully diagnosed and treated was noted by Lett in 1908. Negative exploratory operations have also been made occasionally on children presenting the abdominal crises. Bailey, in 1930, reported 30 cases of abdominal purpura operated upon, of which 14 had intussusception and 16 only intraluminal hemorrhage. Therefore the fact that purpura may mimic intussusception with its abdominal crises and melena, predispose etiologically, or coexist with it should make us alert to all three possibilities.

Symptoms

The cardinal symptoms as presented in this series are listed in their order of frequency in Table 3. This frequency conforms essentially to the recognized pattern of this disease. It should be emphasized that shock is more difficult to evaluate in an infant or a child than in an adult. In our listing of the cardinal symptoms we have placed lethargy and listlessness in the category of shock, believing that they represent moderate forms of impending shock.

Palpation of a rectal mass was possible in seven cases in this series; however, in all of these an abdominal mass was also palpable. Rectal protrusion of an intussusceptum was not noted in this group; however, in our earlier group of patients one was encountered.

The average duration of symptoms in this series is probably not a dependable figure because of the few subacute and chronic cases with durations of three to seven days. Of the acute cases, 39 (68.3%), however, were seen in the first 24 hours, and an additional 10 (84.4%), within the second 24 hours.

TABLE 3.—*Data on Cardinal Symptoms*

Symptoms	No.	Per Cent
Abdominal pain	53	91.3%
Vomiting	49	84.4%
Bloody stool or gross blood on examining finger	47 } 50	81.0% } 86.2%
Markedly positive benzidine	3 }	5.2% }
Palpable abdominal mass	46	77.4%
Shock, lethargy, or listlessness	28	48.3%
Signs of obstruction	21	36.2%
Rectal mass palpable	7	12.0%

Diagnosis

In the typical case of intussusception the diagnosis as a rule is not difficult. The presence of the cardinal symptomatology in a healthy robust infant presenting a classical history of intermittent colicky pain should put the clinician on guard.

The atypical cases, such as intussusception coexisting with or developing during the course of purpura, the chronic intermittent type of intussusception in older children, or the more silent ileoileal types of intussusception where the barium enema column stops at the ileocecal valve challenge diagnostic skill. In such cases procrastination may be, and frequently is, fatal.

TABLE 4.—*Diagnostic Results of Barium Enema Studies Carried Out in Twenty-Eight Patients in This Series*

1	Intussusception diagnosis confirmed	21
2	Unsuspected intussusception found	4
3	Intussusception later proved at laparotomy not shown	3
		28

Roentgenographic studies including barium enema examination were carried out in 28 patients in this series, 5 of whom also had initial flat scout films. Diagnostic results of the barium enema studies in our series are detailed in Table 4. Hence, it is our opinion that x-ray studies for the purpose of diagnosis in intussusception are not necessary in the typical case. Their use in our series as a diagnostic aid has been limited to questionable cases where confirmation of clinical impression is desired, or abdominal signs and symptoms point to the necessity of complete work-up (four unsuspected cases). It is also noteworthy that in this series barium enema studies failed to give the diagnosis on three occasions where subsequent laparotomy revealed the presence of this disease.

In our series the diagnosis was correct in 55 instances (94.8%), including 1 recurrent case, and incorrect in 3 instances (5.2%). Two of these three were diagnosed preoperatively as acute appendicitis, and one as a small bowel obstruction. In the first instance, a Negro girl, aged 6 years, was admitted to the hospital with symptoms of 24 hours' duration and a temperature of 103 F, but had neither bloody stool, abdominal mass, nor colicky pain. Operation disclosed a nonspecific salpingitis with pelvic peritonitis and an enteric, idiopathic intussusception which was reducible. The child made an uneventful recovery. The second case was that of a 12-year-old girl (the oldest patient in the series), who was admitted with a 36-hour history of colicky pain, nausea, and vomiting on two occasions. There was no bloody stool or palpable abdominal mass. On examination there was tenderness and rebound tenderness in the right lower quadrant. The leucocyte count was 13,500, hemoglobin 80%, and urine normal. A preoperative diagnosis of appendicitis was made, and the child was prepared for operation. An ileocecal intussusception to the midascending colon was found. There were associated enlarged mesenteric lymph glands. The bowel was viable, and the intussusception was easily reduced. Recovery was uneventful. The third case representing an error in preoperative diagnosis was one of the purpura cases referred to previously. This patient was operated on, seven days after onset of symptoms and four days after admission, for bowel obstruction due to a chronic irreducible ileoileal intussusception. This was successfully treated with a short-circuiting side-to-side ileotransverse colostomy.

Treatment

In this series of 58 cases of intussusception, 47 were treated surgically by various members of the attending, associate, and resident staff of the Cook County Children's Hospital, 41 by manual reduction. The remaining six cases were irreducible intussusceptions, five of which were treated with primary resection and one with a short-circuiting ileotransverse colostomy (Table 5). While these statements clearly denote our attitude in the treatment of this disease,

TABLE 5.—*Treated Cases*

Surgical	
Manual reduction	35
Manual reduction with appendectomy	3
Manual reduction with repair of ileum	1
Manual reduction with repair of cecum	1
Manual reduction (recurrence)	1
Total	41
Irreducible intussusception	
Primary resection of ileum	5
Chronic ileocecal intussusception	1
Total	6
Nonsurgical	
Barium enema reduction	10
Spontaneously subsided	1
Total	11
Total, all cases	58

it might be well to clarify this stand.

Of these 47 patients treated surgically, 18 had preoperative barium enema studies. Surgery was undertaken in the remaining 29 without its use. In all fairness it should be stated that initial barium enema when used at the Cook County Children's Hospital has been primarily diagnostic. It becomes therapeutic only when fluoroscopic observations reveal ease and completeness of reduction. This result, complete reduction of the intussusception, was obtained in 10 instances in this series.

Some opinion should be expressed as to whether barium enema should be used routinely in intussusception as an initial treatment, or, if not, with what limitations. It is our opinion that the group most suitable for this form of initial therapy should include only the following:

(*a*) those in which duration of symptoms is less than 24 hours;

(*b*) those in which temperature and leucocyte count are normal or show only slight elevation;

(*c*) those in which there is neither shock nor severe obstructive signs;

(*d*) those subacute or chronic cases with duration over four days without toxicity and/or in which confirmation of diagnosis is needed.

Mortality Factors

The extent of bowel damage incurred in intussusception is dependent on several factors, as was emphasized in our previous publication. The incidence of gangrene is much greater in the case with longer duration of symptoms. On the basis of published data plus our own experience, we believe that ileal damage and necrosis far outnumber the instances of cecal or colon damage. Furthermore, most reported resections involve the ileum only. This is understandable because the enteric intussusception or the ileo-ileal-colic intussusception has a much tighter ensheathment of the intussusceptum, thereby causing more vascular occlusion. Snyder has also emphasized the significance of the tightness of the collar of the intussuscipiens. However, unless this is produced by a small ileocecal valve itself, it is usually the small bowel enteroenteric type with its smaller circumference that creates a "tight" intussusceptum.

Irreducibility, leading as it does to a much higher incidence of mortality in intussusception, especially in infants, should be evaluated as to whether the irreducibility is on a vascular (necrosis plus gangrene) or a mechanical (no necrosis or gangrene) basis. Sawyer recently called to our attention a simple maneuver of digital dilation of a tight intussusception which may be tried in instances where no apparent evidence of necrosis or gangrene exists. This maneuver of digital dilation may convert some "irreducible" cases into reducible ones.

The failure to recognize a nonviable bowel and attempting reduction of the intussusception without resection is neither an unknown nor an unreported situation. These factors are examples of erroneous surgical judgment. They must always be considered if intussusception mortality is to be kept low. The other factor of duration of symptoms is primarily dependent upon the continued cooperation of the pediatrician and the surgeon in establishing early diagnosis.

Within the past decade several large consecutive series of intussusception cases have been reported without mortality. Representative among these are the reports of Gross, Packard, Ravitch, and Richter, as well as the cases in the present report. This marked improvement in the management of this condition compared with that of earlier years is striking (Table 6). It would be unreasonable to credit any one specific factor in bringing about this improvement, or to enumerate them in their proper order of value. The past 10-year period has seen the introduction and availability of the broad-spectrum antibiotics. Furthermore, there are reflected the fruits of organized surgical training programs throughout the country. Improvements in our understanding and management of electrolytic, fluid, and nutritional balance have been of no small benefit to surgical patients in general, and particularly those in infancy. Additional refinements in anesthetic techniques and agents as well as better trained anesthetists have largely eliminated many hazards and complications. Last, the continued cooperation of pediatrician and surgeon in the joint management of this disease is a factor which must be given equal recognition in the present success in the management of this condition.

TABLE 6.—*Improvement in Results Obtained in the Treatment of Intussusception in Infants and Children*

Institution	Authors	Period of Observation	No. of Cases	Mortality, %
Boston Children's Hospital	Gross	1948–1950	92	0
Denver Children's Hospital	Packard	1944–1954	86	0
Johns Hopkins Hospital, Baltimore	Ravitch and McCune	1946–1951	57	0
Michael Reese Hospital, Chicago	Richter and Silver	1946–1951	48	0
Cook County Children's Hospital, Chicago	Condon and Oberhelman	1946–1955	58	0
As Compared to Earlier Years				
London Hospital, Children's Division	Perrin and Lindsay	1903–1920	400	34.75
Sydney, Australia, Children's Hospital	Clubbe and Hipsley	1921–1937	286	19.0
Boston Children's Hospital	Ladd and Gross	1908–1939	484	26.9
Babies' Hospital, New York City	Bolling, Hogg, & Donovan	1923–1945	173	21.3
Cook County Children's Hospital, Chicago	Oberhelman and Condon	1925–1945	99	19.1

Comment

The most controversial aspect of the present-day treatment of intussusception in infants and children doubtless exists between those who advocate routine initial conservative measures and those whose preference lies with initial surgical treatment. In the writings of various authors both methods have their advocates. Our opinion lies somewhere between these two extremes. Complete barium enema reductions resulted in the course of diagnostic effort in 10 of our 58 cases, accounting for 17.2% of the total treated. At the same time, barium enema failed to show intussusception where it did exist in three cases. In our experience we did not encounter any complications ordinarily attributed to the initial use of the barium enema; however, the limitations of this method recognized by others

and ourselves were kept in mind, as also were the criteria for its use mentioned earlier in this communication. The use of barium enema as initial therapy in intussusception has its limitations for the following reasons:

(*a*) successful reduction accomplished in only 40% to 60% of cases;

(*b*) incomplete reductions or suspected ones must be surgically explored;

(*c*) false sense of security in the recurrent or high enteric intussusception;

(*d*) overlooking an organic cause where present;

(*e*) possibility of reduction of nonviable gangrenous bowel (which we know is difficult to evaluate with direct inspection) with too vigorous manipulation and enthusiasm of the untrained;

(*f*) time element, which has been shown consistently to be so important a factor in many reports, is allowed to increase.

Additional comment concerning the surgical methods of choice in resections for irreducible, gangrenous intussusception seems pertinent.

Successful primary resection and anastomosis for gangrenous small bowel was accomplished in five cases of this series. This is not an isolated example of a successfully resected series. Dennis and Packard have also recently reported eight and seven cases, respectively, without a mortality. Benson and Sharpe had one mortality in eight resected cases. The consensus of these authors as well as the conclusions from McLaughlin's survey seem to favor primary resection and anastomosis as the method of choice in such cases. Other procedures such as the Lahey-Mikulicz or the obstructive resections, as well as modification of the open bowel resection, have not been productive of any similar degree of success.

Summary and Conclusions

An additional 58 cases of intussusception in infants and children encountered in 57 patients at the Cook County Children's Hospital have been treated without mortality.

A sharp contrast is noted in comparing present mortality with that of former years.

Attention is directed to the notable factors responsible for this gratifying reduction in mortality.

Emphasis is placed on the avoidance of errors in arriving at a correct diagnosis.

Attempt is made to point out the difficulty in recognizing the presence of intussusception coexisting with abdominal purpura.

Barium enema studies have in our hands been primarily diagnostic and were used therapeutically only when certain criteria were met.

Limitations and indications for initial conservative therapy are enumerated, as is our attitude that intussusception in these patients is primarily a surgical disease.

Mention is made of the various operative procedures employed in the treatment of irreducible intussusception in this series, and also the procedure we found to be most successful.

30 N. Michigan Ave.

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DISCUSSION

ON PAPERS BY DRS. SIEBER; BENSON AND LINKNER; AND CONDON AND OBERHELMAN

DR. COLIN C. FERGUSON, Winnipeg, Man., Canada: I am primarily going to discuss the excellent paper given by Dr. Sieber, on intestinal duplications.

I have had a particular interest in this subject since a traumatic experience that I once had. When I was a very junior first-year assistant resident at the Montreal Children's Hospital, one of my first surgical responsibilities was to open up a transverse colostomy that had been performed to divert the fecal stream in a 3-year-old boy. The boy had been born with an imperforate anus, and this had been repaired by the perineal route. He had subsequently been shown to have a recto-vesical fistula. As a preliminary procedure, prior to repairing the fistula a transverse colostomy was done. I was given the job of opening this colostomy one day later.

When I cut across the exposed loop of bowel, I ended up with four openings instead of two. Even at that stage of my surgical training, I knew that that was not proper. It later turned out that the child had a complete duplication of his entire large bowel, with completely separate ceca, appendices, terminal ileums, separate ascending and descending colons; but in the transverse colon, the duplication was fused as one structure, so that it had not been recognized at the time of the loop transverse colostomy (Allard, C. A.; Ross, D. E., and Hopkirk, J. F.: Complete Duplication of Large Bowel Treated by Subtotal Colectomy, *Ann. Surg.* 130:249-252 [Aug.] 1949).

Since that experience I have been very much interested in this problem.

[Slide] This slide shows a very large intestinal duplication in the region of the terminal ileum. I simply show it because this occurred in a premature infant who weighed only 4 lb. 5 oz. (1956 gm.). After the duplication was resected, along with a segment of the normal terminal ileum, the child's body weight went down to 2 lb. 5 oz. (1049 gm.).

[Slide] This shows the experience of the Boston Children's Hospital, where I took some of my resident training. This, of course, is the work of Gross and his associates. (Gross, R. E.; Holcomb, G. W., and Farber, S.: Duplications of Alimentary Tract, *Pediatrics* 9:449-467 [April] 1952). Probably it is familiar to most of you.

Intestinal duplications can do practically anything.

One very unusual duplication in this series originated as a diverticulum from the midjejunum and then extended upward through the right diaphragm, into the right chest, across the mediastinum to end blindly in the left chest. The patient was operated upon with a diagnosis of a right-sided diaphragmatic hernia. He did have a right-sided diaphragmatic hernia, but when Dr. Gross reduced the hernia, there was still one single strand of bowel going up through the diaphragmatic defect. The duplication had to be resected in stages.

A particular problem is the duplication that involves the stomach or duodenum, because in this situation you cannot usually resect it. One can, however, do an internal marsupialization, and this will effectively overcome the problem. Even though duplication may contain aberrant gastric mucosa, fortunately in the region of the stomach this is unimportant, and in the duodenum it does not seem to make too much difference because the duodenal juice neutralizes the acid secretion.

In Winnipeg, in the last six months, we have had three cases of intestinal duplication. Two of these were thoracic duplications, one of which was associated with a spina bifida in the thoracic spine, which made us think that we might be dealing with an anterior myelomeningocele. The third occurred in a 3-day-old infant who presented

with typical symptoms and signs of an intussusception; this is the youngest patient with an intussusception that I have ever seen. A duplication of the terminal ileum was found, which constituted the lead point for the intussusception.

Dr. Sieber has presented a fascinating series of cases. His results are excellent.

DR. WILLIS J. POTTS, Chicago: Just a word about Dr. Benson's and Dr. Linkner's paper on Meckel's diverticulum.

[Slide] In relatively quick succession we had two rather unusual cases of open omphalomesenteric duct.

The open duct was short and attached to the umbilicus. The red mass protruding from the abdomen was obviously covered with intestinal mucosa. There were openings at each end of the mass. With a catheter a bit of barium was injected into each opening. Fluoroscopic observation showed that the barium went toward the cecum when injected into one opening, and into the ileum when injected into the other.

At operation it was found that the peculiar picture presented in this slide was due to herniation of the wall of the ileum through the omphalomesenteric duct. In other words, the mass on the abdomen was actually covered with intestinal mucosa: It was the inside wall of the ileum which had pushed itself out of the open duct.

The second case entirely similar was easily recognized. In both cases surgical correction consisted of simple resection and end-to-end anastomosis of the ileum.

[Slide] I should like to emphasize what Dr. Linkner said about ulcers and bleeding.

The only finding of significance related to Meckel's diverticulum, with exception of infection and mechanical problems, is sudden profuse hemorrhage. Bleeding almost invariably arises from an ulcer in the diverticulum, and the ulcer is situated in displaced gastric mucosa. The blood from an ulcer in a Meckel's diverticulum is characteristic. When a child suddenly, without symptoms, passes a large amount of blood, and if the blood is brick-red, the child has a Meckel's diverticulum. It is not black blood—that comes from the stomach. It isn't pink—that comes from the rectum. It does not have jelly in it—that comes from an intussusception. When a child passes a large amount of brick-red blood, ask the mother whether it was a teaspoonful or half a cupful. If it was half a cupful and is brick-red, the child has a Meckel's diverticulum.

DR. JACOB K. BERMAN, Indianapolis: Drs. Benson and Linkner asked me to say a word about Meckel's diverticulum, and I should like to call attention to the fertile soil for research that this congenital anomaly affords. Indeed, it is an experimental station provided by nature in which we may search for the causes of peptic ulceration with perforation or bleeding, not only in the Meckel's diverticulum, but in all areas where autodigestion of mucous membranes may occur.

Of all persons, 2% are said to have Meckel's diverticulum, and Drs. Benson and Linkner have confirmed previous studies that 90% to 100% of those which bleed have gastric mucous membrane. On the contrary, we may say that if there is no gastric mucosa, in most instances there will be no erosion and no bleeding. This leads to certain implications concerning problems of heterotopic gastric mucous membrane.

Approximately 10% of the adult male population has acute or chronic ulceration of the stomach or duodenum, and more than 30% of these bleed to some degree. Why only 30% instead of 100%? Is it due to ectopic islands of abnormal gastric mucous membrane, or is it due to better local protections?

Yesterday, Drs. Ellis, Andersen, and Clagett discussed peptic esophagitis, and many of these patients have ectopic or heterotopic gastric mucosa, but the exact percentage is not known. A large number of alimentary duplications, which Dr. Sieber described, have gastric mucosa in their lumina.

Meckel's diverticulum with gastric mucosa is associated with a surrounding ileitis. The same is true in gastritis and duodenitis.

In 1936 and 1938 we published a series of experimental and clinical studies on this subject in the ARCHIVES OF SURGERY, under the heading of "Retrograde Duodenogastric Intussusception." We stated that too much emphasis was being placed upon the acid factor, which may be compared to an antigen, rather than on the resisting factors or forces, which may be likened to antibodies.

If a small island of gastric mucous membrane can cause this complication, how much gastric mucous membrane may be safely left in a gastric resection? This question leads to the investigation of one of the resisting factors, namely, the mucous or mucin system, which consists of a large group of merocrine glands distributed widely in all mucous linings of the body.

Mucous membranes, especially those covered by columnar or ciliated epithelium, contain mucous or goblet cells which secrete visible mucus. The stomach and duodenum have sources of mucus from the mucous neck cells and surface epithelium cells, from Brunner's glands and the pyloric glands, which secrete continuously. Mucous chief cells produce dissolved mucin which is alkaline and antiseptic, due to mucoitin sulfuric acid. Mucus contains protein, carbohydrates, mucoitin sulfuric acid, hydrochloric acid, leucocytes, lymphocytes, and desquamated epithelial cells.

Pigs and dogs have more mucous glands in the

esophagus than horses, cats, or man. The pyloric antrum and duodenum are especially well-protected by mucus. Mucus in the intestines comes from the goblet cells in the crypts and plays an important part in absorbing the intestinal enzymes and in the formation of feces. The main constituent of colonic secretion is mucus. If we continuously wash away the protective mucus from the mouth or from the vagina or rectum, the mucosa becomes inflamed.

Francis Bacon, father of inductive (a posteriori) logic, believed in reasoning from observed parts to the whole, from particular to general. A conclusion may thus be drawn from the results of experimentation and observation. Applying this form of logic, we may conclude that mucous membrane, not adequately protected against the digestive action of gastric juice, ulcerates and bleeds.

The deductive (a priori) method of reasoning begins with the premise or hypothesis and goes from the universal to the particular, from all to some, from the whole to its parts. The objection to this type of reasoning is that the major premise may be wrong, yet the logic sound, forcing the reasoner to a fallacious conclusion, as exemplified by the modern sophist.

Applying both methods to the problem under discussion, it follows logically that something which ordinarily protects mucous membrane against erosion by gastric juice is absent in Meckel's diverticulum and in other places where heterotopic gastric mucosa exists.

Therefore, I propose that we search every Meckel's diverticulum with erosion for differences in the number and kind of mucous cells and in the chemical difference in its mucous content. Perhaps peptic ulceration is a systemic disease of the merocrine-exocrine glands with retention of chloride by the sweat glands—the antithesis of so-called mucoviscidosis.

DR. KENNETH E. LEMMER, Madison, Wis.: When Dr. Benson asked me to discuss his paper on Meckel's diverticulum, so ably presented today by Dr. Linkner, I didn't realize that we would have so much discussion of it. Most of the comments I had in mind have already been presented.

Our experience has been much the same as his and Dr. Potts', and we find our mortality is in one of two groups, the obstructive kind or the one that has gone on to perforation. I think that that is the area where we should turn most of our efforts.

The problem of hemorrhage has been ably covered by Dr. Potts. I am sure I need say nothing more about that.

I should like to turn your attention, then, to another phase which I think is important, and that has to do with second childhood. Realizing that 2% of all autopsies show a Meckel's diverticulum present, in the various large operative series we find that Umphrey reported only 9 Meckel's diverticula in 3460 cases of operations, Balfour found 15 in 11,000 cases, and McGlauman found 3 in 14,000 cases. Are we missing asymptomatic but potentially dangerous cases of Meckel's diverticulum?

This was called to our attention recently in an 81-year-old woman in her second childhood who had a perforated Meckel's diverticulum. It was unrecognized for a week. There was no heterotopic tissue. Resection and anastomosis was satisfactory.

Whether or not we should be looking more carefully for a Meckel's diverticulum as we explore, I do not know. I think that we are overlooking a potential source of trouble. If the lumen is large, most of these cases will be asymptomatic. As good surgeons, we should look for a Meckel's diverticulum and record it in our operative notes, whether we resect it or not.

DR. JOHN L. KEELEY, Chicago: I want to say a word about the paper presented by Drs. Condon and Oberhelman.

I am sure we all realize that the difficulty in the surgical management of intussusception is not with those lesions that are reducible but with those that are not. It poses a problem as to management when bowel must be resected. As you know, there are increasing reports concerning the good results from primary resection and end-to-end anastomosis. One is confronted with the possibility of utilizing the exteriorization occasionally, for the reason that it affords immediate decompression. The complications of exteriorization, such as retraction, evisceration, infection, or excoriation, are, of course, avoided by the closed anastomosis.

We have encountered a couple of late cases in the past two years. One patient had an intussusception 36 hours, and another had it 60 hours, both with rather confusing histories. We used a procedure which we thought had some of the advantages of both the primary resection and anastomosis and the exteriorization procedure.

[Slide] This is the preliminary x-ray of the 60-hour case. There are widely dilated loops of bowel. A barium enema showed an irreducible intussusception. As a matter of fact, 10 hours were consumed in getting this moribund child into condition even to study it, let alone do an operation.

[Slide] This shows the procedure that we used. We did a resection and made an end-to-side anastomosis, as you see here, with what turned out to be, anatomically, a distal vent.

Actually, we took the terminal 6 to 8 cm. of

ileum, took away its blood supply, crushed it, let it hang into the colon, and then exteriorized the colon stoma as you see here. We believed that this would give immediate decompression, because anything that passed through the ileum ought to escape through the colostomy, and yet, we should not have fluid loss as soon as material began to pass on through the colon in the normal way. Nothing much came out of the colostomy in either case.

These two cases are not much of a series, I know, but both did very well. We have a follow-up study on each of them.

[Slide] This is the postoperative barium enema in one of the patients. It does not visualize part of the colon, because some of the barium was evacuated before the film was taken, but it does show that when the barium enema is given, there is no difficulty so far as retrograde filling of the ileum is concerned.

As for the colostomy stoma, we closed it with a very simple procedure, mobilizing the stump of colon and turning it in with a purse-string suture and repairing the very small defect in the abdominal wall.

We think that this procedure has a place in the desperate cases that we see. It certainly does not make one put all of his eggs in one basket, so to speak, as does the primary end-to-end anastomosis, and I have a feeling that although many of those cases are reported as successful, probably many of them are done for irreducible intussusception that do not turn out well, and about which we do not hear.

DR. EUGENE A. OSIUS, Detroit: I was very much interested in Dr. Condon and Dr. Oberhelman's paper, and I should like to recite briefly a rather similar experience at the Children's Hospital in Detroit.

We did a 20-year survey, from 1933 to 1953. There were 264 cases in that time. The average time from onset to operation was 42.8 hours. One case had a three-week history; four cases had a one-week history.

During the last five years of the study it is interesting to see that the interval of time has been reduced to 24 hours, which I think is highly important.

The age incidence ran from 15 hours to 10 years. Ninety-two were children between the 4th and 7th month; 67% were seen in the first year; 88% were seen by the end of the second year; 58% were seen between the months of April and September, the incidence during that time being slightly higher.

The overall-all mortality was 16.2%. That does not tell the story. From 1933 to 1938, there were 45 cases with a 44% mortality. I will refer to that again.

From 1938 to 1943, there were 51 cases with 16% mortality. From 1943 to 1948, there were 83 cases with an 18% mortality, all of which occurred before 1945. From 1948 to 1953, there were 85 cases with no mortality.

Another interesting factor was that these cases were done by a number of men—Penberthy, Benson, Weller, Maguire, Louppe and myself, and the residents under supervision. That also is important, the fact that a good figure on mortality can be achieved by a group of men and not by individuals.

There is one other point that I should like to call to your attention, and that is the irreducible cases. From 1933 to 1938, there were four irreducibles, with four deaths. From 1938 to 1943, there were five irreducibles, with four deaths. This gives a mortality of 80%.

In the next period there were five irreducibles, with two deaths, or 40%. In the last period, from 1945 to 1953, there were nine irreducibles and no deaths.

Another point that I should like to ask you to watch for is this: In practically all of these intussusceptions we have noticed a little vascular band that runs across the junction of the ileum and the cecum. It actually produces pressure in some instances, and in practically every instance we have divided that by simply freeing it with a hemostat and clipping it. We have a feeling that that allows the ileum, if it is going to recur, to reduce itself again. It is purely an idea and an observation, and we should be interested to hear if any others have found the same thing.

DR. WILLIAM M. TUTTLE, Detroit: Several years ago Dr. Langston and I reported four duplications of the esophagus, which at that time was a considerable figure. To this date we have duplications of the esophagus, which at that time time, nine, which have been successfully operated on.

The one patient, whose slides I should like to show you today, is rather interesting, and I have not seen a similar case reported. The patient was operated on by Dr. Benson and myself several years ago at the Children's Hospital of Michigan. As far as I know, the patient is still well.

[Slide] This child, just a few days old, was brought to the hospital with what appeared to be a spontaneous pneumothorax. Two tubes were placed in the pleural space, but the child's lung failed to reexpand. It became evident that drainage from the thoracotomy tubes contained milk, and it was believed, therefore, that the child had a pleural-esophageal fistula. Barium studies were done and, as can be seen from the slides, this was apparently the case.

As a result of these studies an exploratory thoracotomy was done. There was a small fistulous

tract coming from the esophagus and entering a small localized empyema space. The fistula was closed by tying it, and the lung was decorticated. The postoperative course was uneventful.

Dr. Leon J. Leahy, Buffalo: I should like to discuss Dr. Sieber's paper on duplications of the alimentary tract.

We have had several such cases at the Children's Hospital in Buffalo, not as many as are reported from Pittsburgh, but ours have varied from one beneath the tongue, with others in the chest and in the abdomen. I should like to mention our most recent case, which was quite complicated. Maybe there is a lesson involved, because I am not sure that it was handled properly by the man who did the original operation.

A 5-month old infant was admitted with a history of bloody stools. The child was thoroughly investigated; it had x-rays, sigmoidoscopic examinations, blood examinations, and no cause could be found. It was transfused and discharged.

At 6 weeks of age the child was readmitted with the same history, and after transfusion it was operated on. It was found that there was a duplication of the entire small bowel to within 10 cm. of the ileocecal valve. The area was resected, and an end-to-end anastomosis was done between the duplication and the normal ileum.

[Slide] This shows the specimen, hemorrhagic on the serosal surface.

[Slide] This shows an ulceration within the ileum, with gastric mucosa on one side of the septum and normal ileal mucosa on the other.

The child did well for two days, had a bowel movement, and on the third day began to have blood in its stools again.

After transfusion it was reoperated on, and at that time the previous anastomosis was taken down, the normal ileal continuity was reestablished, and the duplication was anastomosed to the stomach.

[Slide] This shows the second operation, with ileal mucosa on one side and gastric mucosa on the other, and an ulceration.

[Slide] This is the second specimen, quite similar, six days later.

[Slide] This is what was done at the first operation. The dotted area was resected. On the periphery of the slide you will see that various types of lumen are present.

[Slide] This continues upward and shows the duplication ending in a blind pouch near the ligament of Treitz.

[Slide] This shows what was done at the second operation. The dotted area shows normal ileal continuity reestablished between the upper lumen and the second lumen and anastomosed to the stomach so that the ileum would not receive the insult of gastric juice again.

Since then (three months) the child has been very well, has gained weight, has had no bleeding, has maintained its blood, and looks as if this might have solved the problem. It was too extensive for a resection, and consequently this compromise was done.

Indications for Direct Arterial and Aortic Surgery in Obliterative Disease

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Resection and graft replacement of the aorta and great vessels of the lower extremities for atherosclerosis have passed from the realm of the surgical curiosity to that of the commonplace, and sufficient clinical experience has now accumulated in many surgical centers to warrant critical analysis of the indications for such procedures. The major current interest is centered upon the technical aspects of this problem with only occasional reference to its applicability. Frequently one is left with the impression that the vast majority of persons suffering from arterial insufficiency of the lower extremity are suitable candidates for surgical replacement of their diseased vessels. Such has not been our experience. The purpose of this paper is to review the experience gained in the evaluation of 67 patients suffering from obliterative arterial disease of the great vessels to the lower extremities and to analyze the factors that were considered in selecting patients for surgical bypass or replacement therapy.

Clinical Material

During the 28-month-period from September, 1953, through January, 1956, a total of 67 patients with proved arterial obliterative disease of the aorta or major vessels of the lower extremities were studied at the Denver Veterans Administration Hospital. Data concerning age and diagnosis are shown in Table 1. In each instance the diagnosis has been confirmed by radiographic techniques. Patients with obliterative arterial disease, but not undergoing arteriography because of age, gangrene,

TABLE 1.—*Age of Patients*

	No. of Patients	Mean Age, Yr.	Range
Aneurysms	8	62	59-69
Obliterative lesions			
Aortic	36	54	25-67
Extremity	23	50	27-66
Total	67		25-69

TABLE 2.—*Reasons for Nonoperative Treatment* (42 of the 67 Patients Studied)

Reason	No. of Patients	Per Cent of Total Non-operated Cases
Severe arteriosclerotic heart disease (recent or multiple infarcts or severe angina)	14	34
Negative arteriogram or aortogram (with clinical disease)	11	26
Advanced distal arterial obliterative disease	3	8
Preoperative gangrene	2	5
Died preoperatively	1	2
Severe rheumatic heart disease	1	2
Terminal carcinoma	1	2
Cerebral vascular accident	1	2
Emphysema and cor pulmonale	1	2
Patient refused	7	17
Total	42	100

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From the Department of Surgery, University of Colorado School of Medicine, and the Denver Veterans Administration Hospital.

TABLE 3.—*Anatomic Site of Most Proximal Block** (Aneurysms Excluded)

Location	No.
Immediately below renals	1
Midabdominal aorta	1
Aortic bifurcation	6
Common iliac	11
External iliac and common femoral	12
Midfemoral	16
Popliteal	1

*This does not include 11 patients who had clinical disease and negative aortograms.

TABLE 4.—*Etiology of the Arterial Obstruction and Patients' Age* (Including Aneurysms)

	No. of Patients	Mean Age	Range
Atherosclerosis			
Aortic	44	56	25-69
Extremity (lower external iliac, femoral, and popliteal)	17	54	27-65
Buerger's disease	5	42	31-53
Trauma	1		29
Total	67		25-69

or severe disease elsewhere, were not included in this study.

Of the 67 patients under consideration, operation was performed in 24 (36%). The reasons for refusing operation to the remaining 42 cases are listed in Table 2. The anatomic sites of the most proximally located area of major obstruction, as observed clinically, radiologically, and at operation, are tabulated in Table 3 and Figure 1.

Table 4 indicates the etiology of the arterial obstruction. Although the vast majority (90%) of the cases were due to atherosclerosis, it is becoming increasingly difficult to differentiate atherosclerosis from Buerger's disease. Three young men with histologically proved Buerger's disease have shown obliterative disease of the abdominal aorta of a gross and microscopic character typical of atherosclerosis. On the other hand, varying amounts of inflammatory reaction surrounding arteries involved with advanced atherosclerosis are frequently

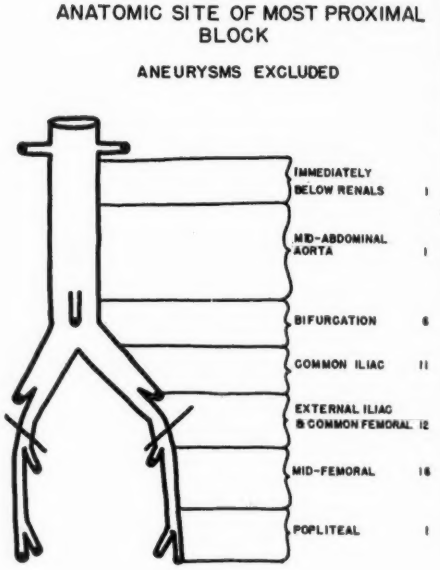

Figure 1

noted. With increasing recognition of atherosclerosis in younger-age groups, this factor cannot be relied upon in differential diagnosis.

In this series essentially every stage of arterial obliteration and obstruction has been observed, varying from minimal narrowing to complete obliteration of the entire abdominal aorta distal to the renal arteries. As might be expected from such an unselected group of cases, the signs and symptoms referable to muscle ischemia have variously been localized in the low back, buttocks, thighs, calf, or feet, depending on the level of maximal arterial occlusion (Table 5).

The types of arterial surgery performed are shown in Table 6. The wide variety of techniques employed reflect our disappointment with certain techniques and progress with others, as well as our benefit from the experience of others during the period of this study. In general, resection and homograft replacement of the aorta and end-to-end saphenous vein bypass graft of diseased femoral arteries are now preferred.

TABLE 5.—*Primary Site of Claudication in Patients with Obliterative Disease*
(Aneurysms Excluded)

Site	No. of Patients	Mean Age	Range
Back	3	53	42-60
Gluteal region	2	50	45-56
Hip	10	53	25-63
Thigh	7	58	45-66
Calf	32	52	26-66
Foot	5	50	32-67
Total	59		25-67

TABLE 6.—*Types of Primary Operations Performed*

	Aortic	Extremity
Aneurysms		
Lyophilized homograft	6	--
Obliterative disease		
Endarterectomy	3	3
Resection and graft	6	6
Bypass	--	1
Total	15	10

Comment

From this clinical experience certain criteria for operability have developed—some through satisfying postoperative results, others by unhappy complications of the procedure employed.

Two complications of atherosclerosis, aneurysmal dilatation and luminal obstruction, furnish indications for surgical intervention. These two clinical entities, even though both are atherosclerotic in origin, must be considered separately in evaluation of indications for operative intervention. Their prognosis for life and limb, their technical excision, and their postoperative results offer vastly different problems. Of the five abdominal aneurysms that we have so far resected, four have been uncomplicated postoperatively and the fifth was a hospital mortality. Since aneurysms present such a different clinical problem, they will not be further included in this discussion.

Evaluation of Operative Criteria

I. Mortality, Morbidity, and a Benign Disease

In our experience the operative treatment of major arterial and aortic obliterative disease has been associated with a hospital mortality rate of 2 patients in 24 operations. In two patients operative intervention has decreased blood flow to the lower extremities. In one of these patients this has been abundantly evident by the necessity for amputation in the immediate postoperative period. It can be argued that these extremities might have required amputation if operation had been withheld, but the fact remains that operation at least hastened the need for amputation.

The morbidity of the successful operations is usually slight, considering the magnitude of some of the operative problems. Exploration or excision of the femoral and popliteal arteries is essentially a minor technical procedure, but even abdominal aortic resection when the graft remains patent carries a remarkably small morbidity. Resection and replacement of abdominal aortic lesions now routinely require two and one-half to four hours, require 2 to 4 units of blood replacement, and may be accompanied by simultaneous appendectomy, bilateral lumbar sympathectomy, and removal or repair of other abdominal pathology noted at the time of exploration, as has been described by others.[1] Postoperative hospitalization is 8 to 21 days. Thus, when the graft functions correctly, there is little morbidity. When clotting occurs in the graft, the situation is sadly reversed, for the morbidity is great, occasionally necessitating amputation. In the replacement or bypass of femoral arterial segments, although late postoperative occlusion is particularly prone to occur,[2] this usually does not produce the disastrous sequelae of aortic or iliac occlusion.

Such an all-or-none operative prognosis is more easily accepted by both patient and surgeon when faced with a malignant or totally crippling disease. Thus, the cardiac surgeon attempting to repair a major con-

genital defect or the surgeon performing multiple organ extirpations for cancer willingly will accept a high operative mortality and morbidity. This is not the case in considering aortic or arterial replacement for obliterative disease, and the statistics relevant to this problem should be so evaluated. A mortality in aortic resection for obliterative disease is a personal catastrophe, not a gallant but unsuccessful attempt for cure in an otherwise fatal disease.

II. Natural History of the Untreated Disease

Unfortunately, there is as yet no authentic standard for comparing a group of patients suffering from atherosclerotic obliterative disease of the extremities treated by arterial replacement with a comparable untreated series.[3] Such studies are urgently needed. Atherosclerotic obliteration of the aorta and iliac vessels has, in particular, only been recognized as an important primary pathologic entity for the past 10 years, and there has been little opportunity to study the untreated disease. Almost as soon as Leriche described the pathologic entity [4] and dos Santos its radiologic visualization,[5] others * demonstrated the feasibility of resecting the maximally diseased vessels, and the majority of patients with segmentally occluded vessels have been so treated.

Atherosclerosis is a progressive disease, but in a given case it may be difficult to predict how adequately the collaterals may compensate for obliteration of the main vessels. Patients have been seen with the aorta totally obliterated (Fig. 2) and with collateral vessels adequate to minimize symptoms of distal ischemia. On the other hand, one cannot count on the development of such limb-saving collaterals, for in four instances we followed the progression of obliterative disease of the aorta and iliac vessels for 12 months or longer, watching the aortographic findings parallel the progression of incapacitating symptoms of ischemia. In one case amputation for frank gangrene was necessary in a man turned down for surgery four months previously because his clinical symptoms and aortographic findings were not thought sufficient to warrant excision and replacement of the diseased vessel. It is evident that one cannot advise watchful waiting in the management of all patients with this condition.

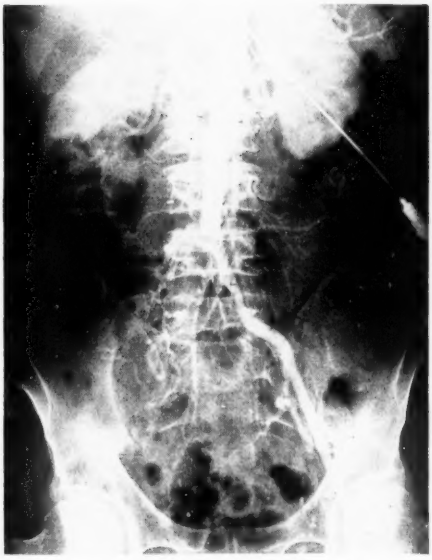

Fig. 2.—A 60-year-old man with a 10-year history of angina and a 5-year history of impotence, claudication of right hip, low back, and thigh. Exercise tolerance of one-half block limited primarily by angina pectoris, not by aortic occlusion.

III. Rate of Symptom Progression

The rate of symptom progression can in general be used to predict the future course of atherosclerosis of the abdominal aorta and great vessels of the lower extremities. Although accurate data are not available in this regard, clinical experience and a knowledge of the pathologic and hemodynamic factors involved support this contention.

By the time a patient consults his physician because of symptoms of hip or leg claudication, or by the time a reduced femoral pulsation is discovered, luminal encroachment is usually far advanced. In the earlier stages of disease, the narrowed atherosclerotic aorta may conduct its volume

* References 6, 7, and 8.

of blood at an accelerated velocity and compensate to a marked degree for the luminal narrowing. At this stage the disease is asymptomatic. By the time that signs of ischemia are apparent, the patient is in an advanced stage of his disease and even slight progression of the obliterative process will produce marked diminution of blood flow (Poiseuille's Law).

Helpful evidence in selecting suitable candidates for operation may be obtained from determining the rate of progression of the disease in relation to the age of the patient. If symptoms of ischemia develop slowly in a patient beyond the age of 50, then one is apt to find advanced obliterative disease of the small arteries of the extremity and a maximum number of collateral vessels. On the other hand, when symptoms develop rapidly, particularly in a younger person, the distal vessels are more apt to be adequate, the collaterals less well-developed, and the viability of the extremity more acutely threatened.

Rapid progression of symptoms may be considered a relative indication for surgical intervention.

IV. Age

Many persons with obliterative disease of the aorta and arteries of the lower extremity will fall within the older-age group, but age in itself is of minor importance in selecting suitable candidates for operation. Persons over 65 have undergone operation without incident, but such older patients are more apt to have atherosclerotic involvement in the small vessels of the extremities, which will compromise the benefits to be obtained by surgery. The ideal candidate is a young person, both because he will better be able to tolerate surgery and, of more importance, he is less apt to have generalized arterial obliterative disease.

V. Coexisting Atherosclerosis of the Heart, Brain, and Kidneys

Although the major clinical manifestations may be in the arterial circulation of the lower extremities, atherosclerosis is a generalized disease. These factors must be given major consideration in evaluating the risk and the benefits of surgical intervention. In most instances there are historical, laboratory, and physical findings consistent with atherosclerosis of the coronary, renal, or cerebral vessels, and each case must be evaluated individually on three counts: (1) operative risk; (2) prognosis and life expectancy on the basis of coexisting arterial disease other than in the extremity, and (3) the possibility of the patient engaging in increased activity when the obstructive lesion in the legs is corrected. The first two factors are self-explanatory and differ little from medical evaluation for any elective surgical procedure. The third factor is, however, unique, for little is to be gained if the excellent results of arterial replacement allow the patient to exert himself to the point where he experiences anginal pain, or more serious signs of coronary insufficiency. Thus, two of our patients experienced myocardial infarction following successful aortic resections. The poor prognosis in this group of patients is reflected in the fact that within a 12-month period after being evaluated for direct arterial surgery 4 of the 67 patients died of coronary thrombosis and 4 other patients died of other causes.

The presence of advanced coexisting atherosclerosis has been the major reason for rejecting candidates for surgery in this study (Table 2). The actual percentage of patients considered suitable for operation could be altered at will, depending on how frequently one wished to consider direct arterial surgery in patients being seen primarily for atherosclerosis of the heart, kidney, or brain.

The ideal candidate for direct surgical intervention for obliterative disease of the lower extremity is one who has atherosclerosis maximally concentrated in one segment of the abdominal aorta, or in the vessels of the thigh, but with minimal involvement of the remainder of the arterial tree.[9]

VI. Condition of the Artery Distal to the Graft Site

Atherosclerosis is a generalized disease. This fundamental fact must constantly be considered in evaluation of patients for excisional arterial therapy.

In this series of patients a sharply demarcated segmental atherosclerotic block surrounded by completely normal vessel was not observed. Invariably there has been diffuse atherosclerosis with a variable amount of luminal encroachment on each side of the segment of maximally diseased vessel. Since success in the direct surgical approach to arterial obliterative disease depends largely on the status of the vessels distal to the bypassed or excised section of artery, evaluation of distal vessel disease is of prime importance. Clotting within the graft occurs because of poor vascular flow, which, in turn, usually is secondary to distal obliterative disease. When clotting has occurred within the graft, there has invariably been evidence of advanced distal obliterative disease. The ultimate prognosis has then been poor despite embolectomy, replacement of the graft, or the immediate use of vigorous anticoagulant therapy.

Since the lack of obliterative disease distal to the graft site is so vital to a successful operative result, the evaluation of the distal vessels assumes critical importance. Methods for such evaluation include clinical evaluation of the distal portion of the extremity, radiographic visualization of the vessels, and direct exploration of these vessels at operation.

(*A*) *Physical Examination of the Calf and Foot.*—The relative patency of the arterial system of the calf and foot often is reflected in both the signs and symptoms of ischemia in this area. As has been shown by others,† the location of claudication in aortic and iliac disease is usually in the back, hips, and thighs. Similarly, when there is advance obliterative disease in the smaller vessels of the calf and foot, claudication occurs at this point. Localization of symptoms at this point suggests a poor prognosis for direct surgical approach on more proximally located vessels. Only occasionally will patients with moderate peripheral disease and advanced obstruction of the iliac vessels complain of calf claudication.

Signs of tissue ischemia in the calf and foot, such as muscle wasting, atrophic skin changes, lack of hair, and slow toenail growth, indicate obliterative disease in the vessels of this area. Persons with healthy-looking feet and legs and showing none of these changes normally have minimal small-vessel disease in the lower leg and are good candidates for aortic or femoral arterial replacement.

Examination of the pulse in the lower extremity has been of limited value in selecting patients for operation. In most instances where claudication is sufficiently disabling to consider surgical therapy, the pulses distal to the femoral region are absent. Where femoral arterial bypass is being considered, the presence of a strong femoral pulse is some assurance that an adequate proximal blood flow is guaranteed. A bruit or audible systolic murmur over a major arterial segment indicates partial obstruction of the lumen in that area.

(*B*) *Aortographic Findings.*—Radiologic visualization of the diseased vessels is usually unnecessary to establish a diagnosis of atherosclerotic obliteration of the larger vessels. With increased experience and attention to the location of the discomfort resulting from exercise, the proximal level of maximal obliteration normally can be predicted. The proximal level of block is, however, of relatively little importance in the aorta, since atherosclerotic plugs can be removed by endarterectomy even when they extend proximal to the renal vessels. In the preoperative evaluation of persons with femoral arterial block, the most proximal level of obliterative disease is of much greater significance, since the proximal end of the graft must lie at a point where there is adequate blood flow.

The major benefit of aortography and

† References 4, 7, and 8.

arteriography, therefore, is the information it furnishes as to the extent of the obliterative disease distal to the main point of obstruction—a factor which we have found to be of overwhelming importance in determining the continued patency of a vessel graft.

Arteriography also furnishes information as to the extent and location of collateral vessels around the arterial block—a helpful preoperative aid in planning the operative procedure and avoiding the loss of important collateral vessels.

(*C*) *Operative Exploration.* — Routine femoral artery exploration was performed in the earlier aortic resections, but it was soon learned that in most cases the status of these vessels could be predicted by other means. Occasionally, when it is suspected that distal vessel involvement is so severe as to contraindicate aortic resection, the femoral artery is visualized, palpated, and, if necessary, the lumen is openly inspected. Such procedures have become progressively less frequent, but on two occasions aortic resection was rejected after such exploration.

Where major obstruction is in the femoral vessels, on the other hand, the distal end of the vessel is routinely first explored, for in these cases major disease is frequently found extending below the popliteal region. On three occasions further surgical efforts were abandoned when preliminary exploration of the popliteal artery showed total or almost total obliteration of the lumen.

Summary

The indications for excision or bypass of the aorta and great vessels of the lower extremities for atherosclerotic disease are reviewed on the basis of a series of 67 patients, of whom 25 were selected for operation.

The factors considered in this elective procedure are morbidity and mortality, age, natural history of the untreated disease, degree of incapacitation, progress of symptoms, evidence of disease distal to the point of surgical attack, arteriographic findings, and evidence of disease elsewhere.

It is emphasized that atherosclerosis is a generalized disease and that relatively few patients suffering from ischemia of the lower extremity are suitable candidates for surgical excisional or bypass therapy.

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End-to-Side Bypass Homograft Without Resection in Segmental Arterial Occlusion

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The bypass principle in the treatment of segmental vascular occlusions was apparently initiated by Kunlin and associates [1] in 1951, who employed an autologous vein to bridge an arterial occlusion. However, only in the past year or two, with the use of homologous arterial grafts, has the principle enjoyed widespread acceptance and application. The arterial graft seems to have definite advantages over the venous graft. Several American surgeons * have already reported quotable success in large series of patients with arteriosclerotic occlusive disease of the lower extremities treated by bypass arterial grafts.

Reasons for the popularity of this method are obvious. The risks inherent in endarterectomy or in arterial resection with graft replacement appear to be virtually absent in the bypass operation. Existing circulation is not disturbed and is therefore not endangered. The incidence of failure appears to be less than that of other procedures. Unless an occlusion progresses rapidly in the host vessel, failure of a bypass graft results in no worse circulatory status than had been present prior to surgery. Reoperation in the event of failure is usually feasible and may be successful. The simplicity of the technique makes the operation adaptable by a large number of surgeons.

Shaw and Wheelock [5] used resection and end-to-end anastomosis of an arterial graft for occluded segments of 15 cm. or less; for longer occlusions they employed end-to-end anastomosis above or below, with bypass and end-to-side anastomosis to the host vessel at the opposite end of the graft; for occlusions extending as high as the origin of the superficial femoral artery they employed end-to-side bypass grafts. Crawford and associates [3] resected and grafted short arterial blocks with the end-to-end technique, but employed the bypass principle for longer occlusions.

We applied the bypass technique to short as well as to long arterial occlusions on the premise that anastomoses can thus be made far enough away from the occlusion proximally and distally to assure working with the best possible arterial wall in the host, and with minimal dissection. Furthermore, in an effort to establish limitations of the procedure, we performed it in certain borderline cases in which the peripheral vascular bed was of questionable patency.

We now perform routine arteriographic examination of every patient with symptomatic occlusion, provided no contraindication exists. We believe that only by this means can patients suitable for direct surgery be separated from those for whom conservative therapy or sympathectomy is more desirable.

Clinical Data

The proportion of patients with ischemic symptoms who demonstrate segmental oc-

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From the Departments of Surgery, Northwestern University Medical School and Veterans' Administration Research Hospital, Passavant Memorial Hospital, and Evanston Hospital.

* References 2, 3, and 4.

clusive lesions is apparently higher than usually supposed. Szilagyi and Overhulse [6] found that 10% to 15% of their patients with symptomatic inadequacy of blood supply to the legs had segmental blocks. Shaw and Wheelock [5] found that 25% of femoral artery occlusions were segmental in nature. Crawford and co-workers [3] report that the segmental blocks existed in some 50% of femoral artery occlusions and in nearly all patients with inadequate iliac arterial flow.

In our experience, 78.3% of patients with ischemic symptoms of the legs exhibited occluded femoral or iliac arteries. Of this group, 74.2% were suitable for bypass surgery. Thus, the patients considered suitable for operation by roentgenographic criteria comprised 50% of 46 extremities subjected to arteriographic examination.

We have performed 19 bypass procedures upon 17 extremities in 15 patients. The patients ranged in age from 46 to 69, and all but one were men. In each instance the indication for surgery was intermittent claudication or ischemic pain of other types associated with an impalpable pulse distal to the occlusion. One patient had gangrene of the great toe. The occlusion was in the femoral artery in 16 extremities, in the iliac artery in 2, and in the iliac-femoral-popliteal in 1. The pathology in every case was that of occlusive arteriosclerotic disease. Arteriography was done by the transaortic route in about one-third of the patients, and retrograde through a pulsating femoral artery in two-thirds.

The occlusions varied from 2.5 cm. in length to total absence of a lumen from the aortic bifurcation to the popliteal artery. The vast majority occurred in the femoral artery. The distal run-off was estimated as poor in two extremities and fair in three. The remaining cases appeared to have an adequate distal vascular bed.

Calf pain in the preoperative period varied from a claudication distance of less than 25 ft. to 3000 ft. at 120 measured steps per minute. Other preoperative measurements included oscillometric and skin temperature tests.

Patients were denied bypass surgery only for the following reasons: (1) myocardial damage of such severity that improvement in circulation to the legs may have led to more ambulation than the cardiac status could tolerate; (2) almost complete absence of distal arterial run-off; (3) total absence of popliteal artery lumen.

Surgical Technique

Material for grafting consisted of femoral and iliac arteries which were obtained from qualified cadaver material and preserved by lyophilization according to a technique previously described.[7] If the bypass was to extend from the region of the upper thigh to the popliteal area, two limited incisions were used, similar to the method described by others† (Fig. 1). Even when the actual occlusion appeared only a few centimeters in length, the lumen of the vessel proximally and distally was often so narrowed by arteriosclerotic plaques that a long graft was employed to extend

† References 2 and 8.

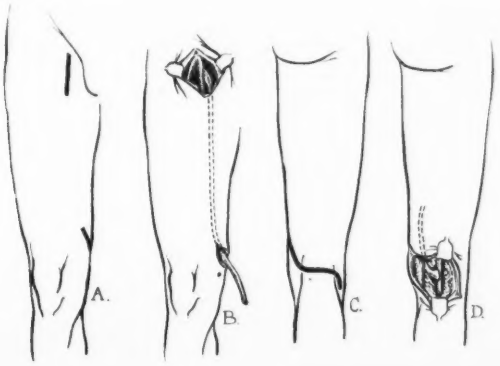


Fig. 1.—Incisions for femoral-popliteal bypass graft. Upper incision is closed before patient is turned over.

from well above the occlusion to a suitable site below. In four instances it was necessary to anastomose graft to graft in order to obtain sufficient length for the bypass. If the graft extended from the iliac to the femoral arteries, the iliac exposure was made abdominally and a separate incision was made over the femoral area. The graft was then threaded through the femoral canal, which was slightly widened by finger dissection. Short femoral-to-femoral grafts can often be handled through a single incision, although in our series all cases were done with two or more incisions.

The upper anastomosis was made first in 13 instances, while in 8 the lower area was explored first. After selecting an appropriate site on the host vessel, the vessel was mobilized and a proximal clamp was applied. A dose of 5 cc. of 20% heparin solution was injected distal to the clamp in order to maintain patency of collateral channels.‡ Clamps were then applied above and below the site of anastomosis. An oval window was cut in the host vessel, and the end of the homograft prepared in the manner shown in Figure 2. This technique, essentially that of Linton,[2] has the advantage of permitting a wider flare than an ordinary bias cut. Everting keystone stitches were placed at the lower and upper ends of the oval to attach the graft to the side of the vessel. The anastomotic row of stitches was then completed either by a continuous over-and-over suture or by an everting in-and-out suture. In the aorta and iliac arteries 0000 arterial silk was used, and in the femoral and popliteal arteries, 00000 arterial silk.

‡ Three early patients also received systemic heparin during surgery.

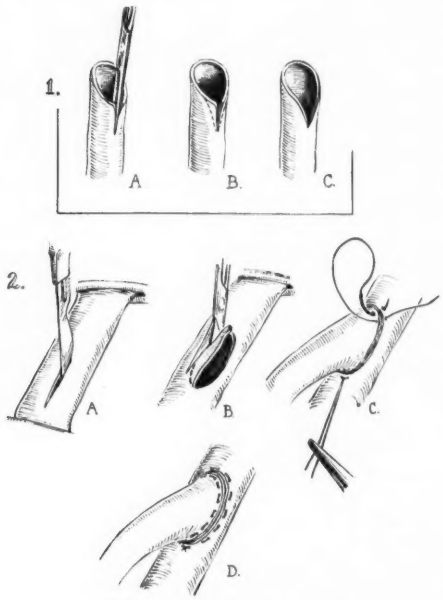


Fig. 2.—Method of shaping end of arterial homograft to permit flare of vessel after anastomosis (*1A, B, C*). Oval window cut in host vessel and method of anastomosis (*2A, B, C, D*). In some cases an everting over-and-over suture is used for the anastomosis.

After completion of the upper anastomosis, the graft was filled with heparin solution § and any leaks repaired. With a clamp on the distal end of the graft the clamps were removed from the host vessel, allowing pulsating blood to fill the graft. Any imperfections in the anastomosis were now repaired, either by an extra stitch or by simple pressure. The tunnel through which the homograft was to course was then developed by the fingers or by a large probe. When anastomoses to the popliteal artery required turning the patient, the distal end of the graft was brought out through a small incision at the medial aspect of the upper popliteal area, and the upper skin incision was closed. The popliteal exposure was made through a horizontal S-shaped incision connecting with the small incision through which the pulsating graft had been brought previously. After exposure of the popliteal artery the graft was usually passed under the tendons of the medial hamstring muscles. The excess length was removed from the graft, and the anastomosis between graft and popliteal artery was carried out in the same manner as described above.

The wounds were closed without drainage.

The wounds were dressed with gauze and elastic adhesive plaster, care being taken not to encircle the limb.

If the bypass was not brought to the popliteal area, ambulation was usually allowed in 48 to 72 hours. Patients in whom the graft extended to the popliteal artery were kept in bed for five days before permitting graded ambulation.

Results

Published results with the bypass homograft procedure are at great variance. Crawford and associates [3] report an 86% success with their cases of femoral artery grafts, most of which were followed for from six months to two years. Hoye and Warren,[4] on the other hand, report that none of their five end-to-side bypass procedures (includ-

§ Twenty milligrams per 10 cc. isotonic solution of sodium chloride.

ing those mentioned in the addendum) remained patent for more than a year. Four were occluded in about six months.

We have analyzed our results on the basis of immediate and delayed effects. Success or failure was determined by the presence or absence of a restored pulse distal to the graft. Of the 19 bypass grafts, 15 resulted in a restored distal pulse in the treated extremity. In 14 instances (73.7% of the total) either or both the dorsalis pedis or posterior tibial pulses at the ankle were restored shortly after surgery. In one, the popliteal artery below the graft had good pulsations not previously present, but the ankle pulses remained absent. The pulses returned immediately upon completion of surgery in 11 of the 15 initially successful cases, while in the other 4, the pulses returned in from four hours to seven days postoperatively. Of the 19 grafted extremities, 10 were followed for more than six months; the last 9 cases were done less than six months prior to this writing.

Of the cases followed 6 to 10 months, there were four delayed failures, two due to occlusion (4 months and 2 weeks, respectively, following surgery, both in the same extremity), and two due to rupture of the graft 6 days and 3 weeks postoperatively. These cases are described in detail below.

The over-all failure rate, then, including 4 immediate and 4 delayed failures was 8 out of 19, or 42.1%.

Some subjective or objective evidence of symptomatic improvement was noted in two of the so-called failures, as shown by a lengthened claudication distance. In one of these cases the skin temperature improved and remained higher than in preoperative measurements. In three failures a subsequent sympathectomy was performed, while in two a new bypass was inserted around the previous one.

Complications.—1. Postoperative Edema: This unexpected but interesting complication was encountered as a persistent symptom after 10 (66.7%) otherwise immediately successful grafts. In these patients the edema was persistent enough to present a therapeutic problem. In practically every case a transient edema, lasting 48 to 72 hours, occurred. Persistent edema, lasting from one week to four months following revascularization of an extremity, has been given almost no attention in previous reports.

Search for the cause of the edema indicated that it was not due to venous or lymphatic stasis. Analysis of our cases revealed that in 8 of the 10 extremities a bypass graft of over 30 cm. in length had been inserted. In most of these instances there was a marked difference between the caliber of the host vessel above the occlusion and that of the host vessel below. Thus, a large column of strongly pulsating blood was being forced through a new conduit, without intervening branches, into a narrow channel below. The resultant strain upon the small vessels of the outflow bed conceivably caused increased arteriolar and capillary permeability and resultant edema.

This supposition was supported by the

Data on Immediate and Delayed Effects with the Bypass Homograft Procedure

Total Bypass Grafts	Immediate Success	Immediate Failure	Delayed Failure	Total Successful Results	Total Failures
19	15	4	4 (6 days, 2 wk., 3 wk., 4 mo.)	11 (58.9%)	8 (42.1%)

Symptomatic Improvement.—All patients in whom a distal pulsation returned were markedly improved in their ability to walk further than before. Pain was relieved in every case but one, in which a moderate degree of heel pain persisted.

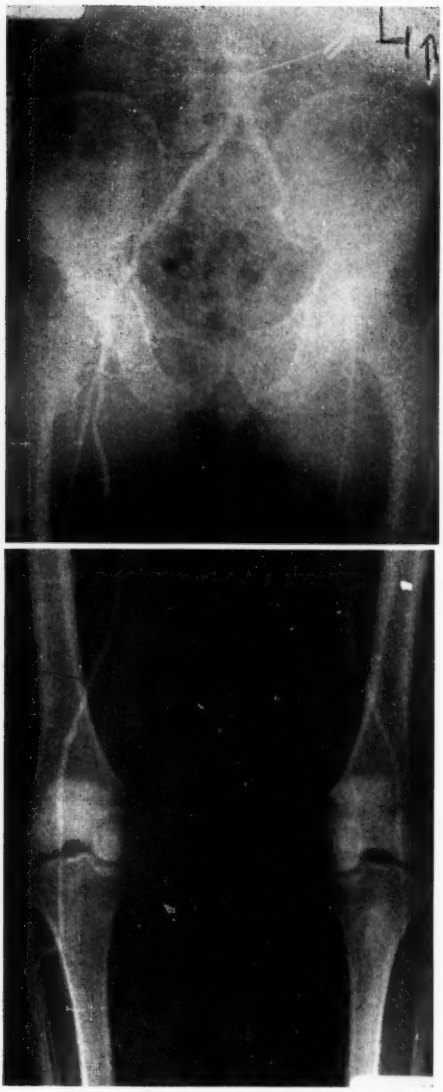


Fig. 3.—Bypass graft from common iliac to femoral artery, passing through femoral canal.

fact that in two instances of delayed occlusion of a graft following surgery edema of the foot and ankle disappeared within a few hours after the graft became occluded.

2. Bleeding: In three of the patients operated upon early in the series, systemic heparinization was instituted during surgery. In one of these patients a retroperitoneal hematoma and paralytic ileus developed after insertion of an iliac-to-femoral bypass graft. In another, a hematoma developed in the upper thigh wound after a femoral-to-popliteal bypass; this graft ruptured near the upper anastomosis three weeks postoperatively. The third patient subjected to systemic heparinization developed no complications. Needless to say, the practice of systemic heparinization during

or after surgery was discontinued in subsequent patients. However, the local instillation of heparin into the distal host vessel at the time of surgical occlusion is still considered very essential.

In addition to the ruptured graft mentioned above, one additional graft ruptured. This patient had had a bifurcation bypass from the aorta to common femoral artery on the left side and to the popliteal artery on the right. Six days postoperatively the long graft on the right ruptured in the midfemoral area. The segment was excised and replaced, end-to-end, by an intimectomized strip of host femoral artery, but without success.

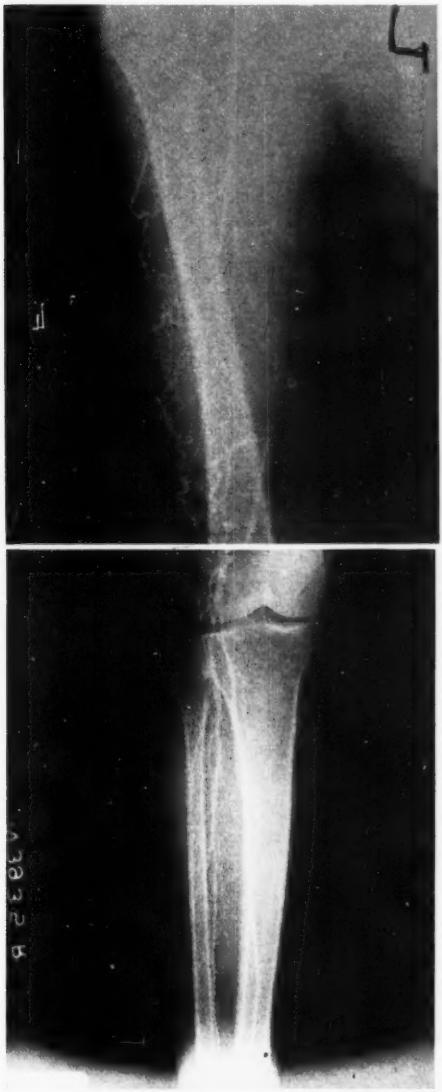
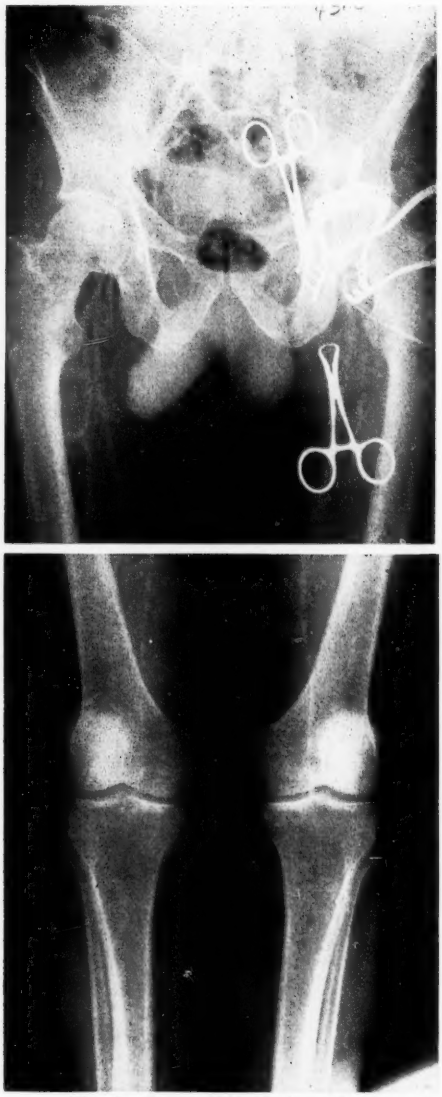


Fig. 4.—Example of excellent distal run-off. Bypass graft extends from common femoral to upper popliteal artery.

Analysis of Failures. — A retrospective analysis of both the immediate and delayed failures was made in an effort to improve our future selection of patients and techniques of therapy.

In three of the four immediate failures, the distal runoff was considered poor to fair after reexamination of the preoperative arteriograms. As our experience grows, judgment of the adequacy of the distal arterial tree is becoming more accurate. One of the patients with an immediate failure had had a previous end-to-end vein graft placed in the femoral artery at another institution, without success.



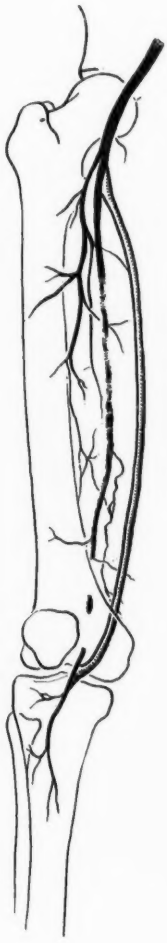


Fig. 5.—Retrograde arteriography done through femoral artery on unaffected side. Graft bypasses all questionable areas of the femoral artery. Distal run-off fair to poor. Distal pulses did not return in this case.

Technical error resulted in the other immediate failure. This patient was subjected to a percutaneous femoral arteriogram the day before surgery. The arteriogram revealed a segmental occlusion in the femoral artery with excellent distal run-off. However, at the time of surgery a thrombus was found to fill the entire femoral artery. This was aspirated and the operation completed, but pulses did not return below the graft. We believe that it was an error to do the arterial puncture and injection of

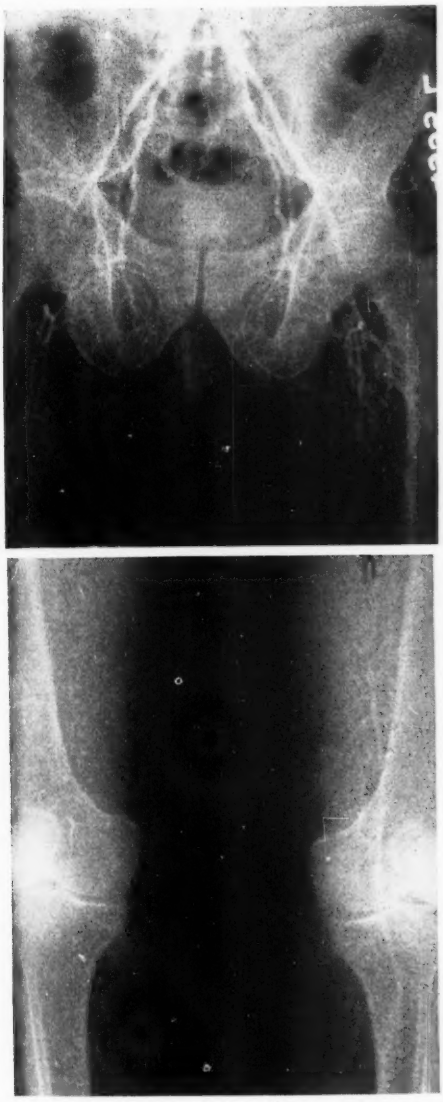


Fig. 6.—Bilateral occlusion of femoral artery. Extremity on the left (patient's right) shows virtually no popliteal lumen, therefore is not amenable to bypass surgery. The other extremity shows fairly good popliteal run-off. Graft placed from common femoral to popliteal artery.

radiopaque medium on the same side and in approximately the same area of the contemplated surgery.

Of the four delayed failures, two were mentioned above. One patient had an apparently successful result, with excellent pulsations at the ankle for three weeks. A large hematoma had developed in the upper thigh wound shortly after surgery owing to systemic heparinization. This was evacuated, but local proteolysis eventually resulted in rupture of the graft. A secondary graft

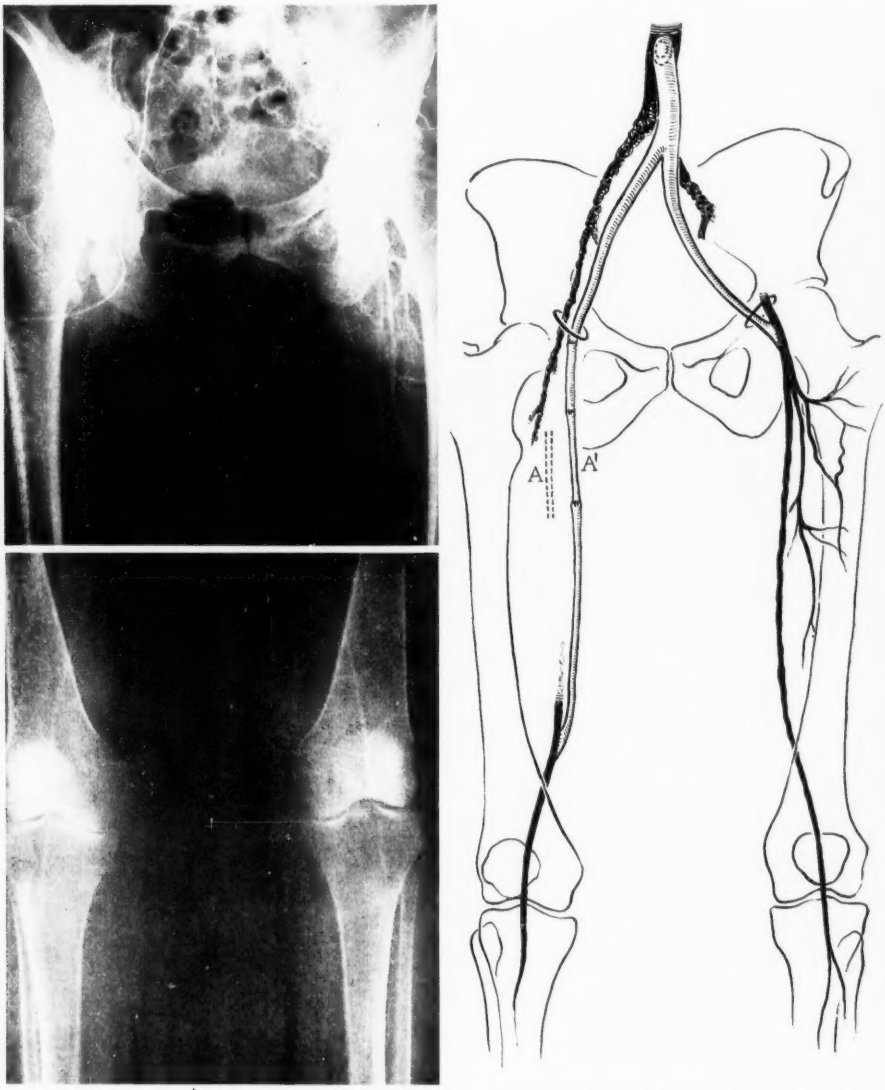


Fig. 7.—Bifurcation bypass graft from aorta to common femoral artery on patient's left side, and to popliteal artery on opposite side. Good pulses restored to both extremities, until large graft ruptured in midfemoral area after six days. At emergency reoperation, segment of occluded host vessel (*A*) was intimectomized (because new homograft was unavailable) and was sutured into graft (*A'*). See Text.

was later placed around the initial graft, with a successful outcome.

The other previously mentioned delayed failure occurred six days postoperatively, apparently the result of a defect in the graft, resulting in rupture.

The other two delayed failures occurred in one patient. His first graft functioned very satisfactorily for four months, at which time it suddenly became occluded while the patient was walking. The suddenness of the occlusion knocked him down. Prior to surgery, the run-off appeared excellent. We concluded, therefore, that the

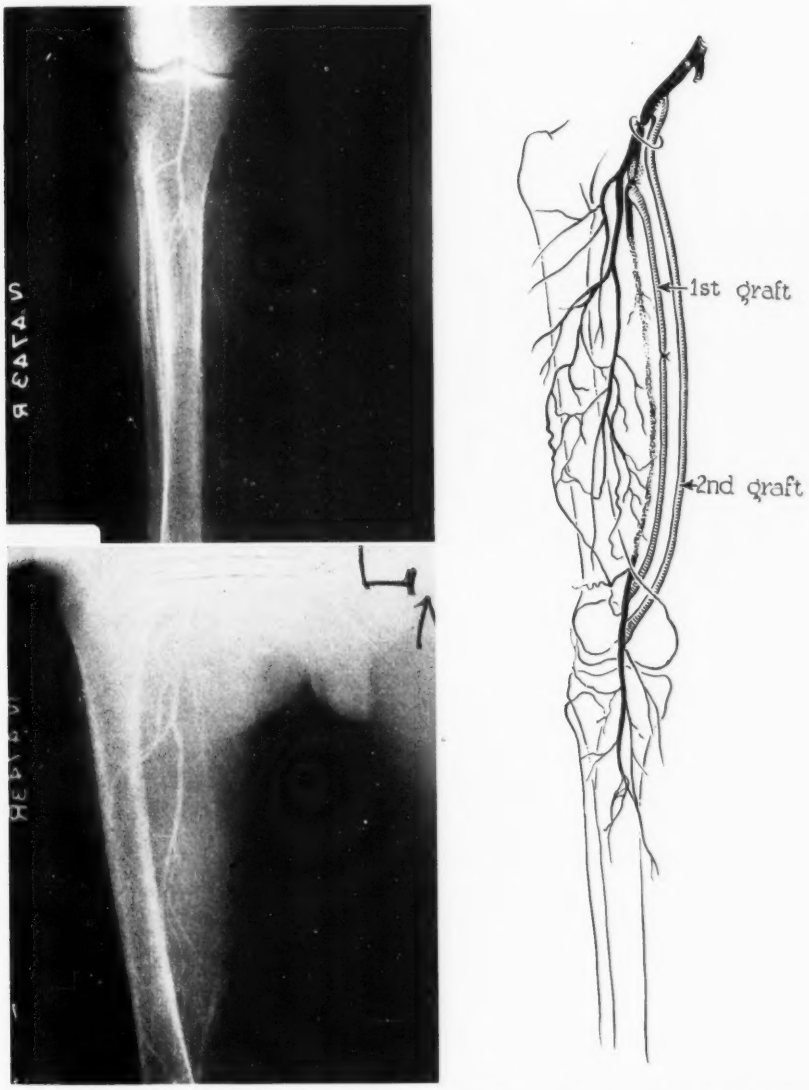


Fig. 8.—Proteolysis following hematoma at site of upper anastomosis resulted in rupture of first graft and erosion of host vessels, necessitating ligature of common femoral artery, and obligatory secondary bypass from external iliac artery to popliteal artery. Satisfactory result.

graft may have become occluded by an embolus. Subsequent sympathectomy yielded no improvement. After several weeks a secondary bypass procedure was done, this time in the presence of only fair distal circulation. The second graft was successful for exactly two weeks until it, too, suddenly became occluded. The sudden nature of the two occlusions of this patient's grafts indicates that they may have been due to embolization of displaced arteriosclerotic plaques from the host vessel above.

Summary of the failures indicates that the prime cause of failure is inadequacy of the circulation distal to the segmental occlusion. Choice of candidates for bypass surgery should be governed by this important consideration.

Secondary Surgical Procedures.—An advantage of the bypass procedure is the feasibility of performing a secondary bypass in the event of failure, without endangering collateral channels. As mentioned above, we performed two such secondary procedures, one following rupture of a graft, and one following occlusion. The former was successful, the latter failed after two weeks.

Three of the failures in our series were subjected to lumbar sympathectomy. It resulted in questionable-to-fair symptomatic improvement.

Comment

Application of the bypass principle to arterial occlusions of several different types has given us an opportunity to study its advantages as well as its limitations. Because of its relatively simple technique and negligible risk, the end-to-side bypass lends itself readily to virtually any type of segmental arterial occlusion in the lower extremity. Selection of patients with adequate peripheral run-off appears to be of prime importance, although many with less than adequate distal circulation obtain some benefit. Some of these patients recover a distal pulse but develop postoperative edema of the foot and ankle; others do not experience a resumption of distal pulse. While long grafts usually succeed, there appears to be a greater risk of failure in long grafts, particularly those anastomosed to the lower portion of the popliteal artery. A direct relationship between the inadequacy of the peripheral small vessel bed and the extent of popliteal artery occlusion seems evident. Thus when only the most distal portion of the popliteal artery appears patent on the arteriogram, the outflow bed is usually inadequate. Also, the anatomic position of the low anastomosis may be conducive to early secondary blockage because of the motion of the knee joint. Poor outflow from the anterior and posterior tibial artery branches occasionally exists even in the presence of a good length of reasonably patent lumen in the popliteal artery.

Patients with severe cardiac, renal, or pulmonary disease were usually not accepted for surgery merely because of claudication. Additional activity and ability to walk only would have added to the burdens of their cardiac or other disease. Nonetheless, many poor-risk patients can tolerate bypass surgery of the lower extremities extremely well, because the procedure may be carried out entirely under local anesthesia. Ten of our patients were handled in this manner.

In addition to the advantages of preservation of collateral flow, limited dissection, and negligible risk to life and limb, the bypass procedure is amenable to secondary surgery when necessary. It is possible to successfully bypass a bypass provided a reasonably good distal arterial bed remains. If secondary direct surgery is not deemed feasible, one may resort to sympathectomy.

Long-term follow-up is planned in order to determine (*a*) the incidence of sclerotic changes in the grafts; (*b*) the maintenance of patency of the graft; (*c*) the persistence of patency in the distal small vessel arterial bed, and (*d*) the natural history of patients with grafts as compared with patients treated by indirect methods.

Summary

A high percentage of patients with

ischemic symptoms of the lower extremities have segmental arterial occlusions amenable to bypass surgery.

The bypass procedure appears to have wide applicability because of its several advantages.

The crucial factor in the success of bypass arterial surgery appears to be the adequacy of the distal circulatory bed.

Postoperative edema often develops following surgery, especially when the graft is long and when the distal host vessel is narrowed.

Immediate success in restoring distal pulsations was obtained in 15 of 19 bypass grafts. Four delayed failures occurred six days to four months postoperatively, two due to delayed occlusion and two due to rupture.

The circulatory status of the limb subjected to surgery was not worsened in any case, regardless of failure of a graft to function. There was no mortality.

In some instances of failure to restore pulses to the ankle vessels, symptomatic improvement was seen nonetheless.

Reoperation was carried out in two instances of failure, with one successful result.

Addendum

None of the results described in this series of bypass operations have changed in the six months subsequent to the initial writing.

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DISCUSSION

ON PAPERS BY DRS. EISEMAN, RAINER, MALETTE, AND HUFFMAN; AND LAUFMAN, HOHF, BERNHARD, AND TRIPPEL

DR. R. E. TABER, Iowa City: I think it is difficult to talk about this type of surgery without talking about the indications, as Dr. Eiseman stated.

I should like to show you briefly a technique that we are using for aortography which has been of distinct help to us in selecting these patients for surgical treatment.

[Slide] We believe that the adaptations and simplifications of this technique, which is not original with us, have made it a reasonably practical procedure to carry out on almost any patient who is to be evaluated for this type of surgery. We have not used it on patients who are being considered for resection of aneurysms nearly as frequently as we did in the past. However, patients whom we consider for lumbar sympathectomy or some type of direct arterial surgery have been studied by this technique.

An x-ray table is used which allows adequate clearance of the x-ray tube, which is a distance of 4 to 5 feet above the table. We use a wedge-shaped filter made out of aluminum, placed across the outlet of the tube at this point, and this gives a difference in radiation penetration in the extremities as compared with the thicker abdomen and lower chest.

The cassette tunnel is made of plywood. Two Lysohlm grids are taped together on top of the cassette tunnel. Through the tunnel we pass the x-ray cassettes [Slide], which are 12″×36″ in size. Four cassettes are passed by a team of x-ray technicians through the tunnel in a period of 8 to 10 seconds. Visualization of the arterial tree is possible from the level of the diaphragm

to the junction of the middle and upper thirds of the calf in the majority of patients.

[Slide] This shows an aortic bifurcation block extending proximally to the inferior mesenteric artery at this point. The thigh and upper calf vessels are visualized to this level.

DR. D. EMERICK SZILAGYI, Detroit: Dr. Laufman very kindly asked me to comment on his paper dealing with the complete fermoral bypass operation. Before doing so, however, I should like to say a word about Dr. Eiseman's paper which impressed me very much with its forceful and clear presentation. I regret to say that I do not agree with some of its conclusions.

Our experience with grafting therapy for peripheral occlusive arterial diseases comprises 120 operations performed during the past three years. The fact that these cases were selected from among the group of about 100 lesions with segmental occlusion clearly shows that our operative indications are different. Whereas Dr. Eiseman finds 40% of his cases suitable for direct surgical approach, our proportion is nearer 80%. Such a wide discrepancy may partly be due to differences in clinical material, but perhaps more importantly it must result from a different philosophy in interpreting the factors, so well listed by Dr. Eiseman, that one must weigh in selecting cases for operative treatment. Since time does not allow the analysis of these factors one by one, I should like to summarize very briefly our own operative indications.

It should be stressed that the mere presence of a segmental occlusion in an angiogram is not an indication for grafting therapy. If, however, the patient's symptoms are severe enough to interfere with his mode of life or in particular with his occupation, one is justified in considering corrective surgery. If by angiography the inflow and outflow tracts proximally and distally to the occlusion seem adequate to assure patency of graft, surgical exploration is in order; and if the operative findings confirm the angiographic appearances, the insertion of a graft by an appropriate technique is indicated. From this situation one proceeds by stages to the case where gangrene of the extremity is impending and where, in order to save the limb, a grafting procedure is called for, even in the presence of less than satisfactory anatomical and pathological findings. The grafting operations performed on the basis of these criteria showed an immediate success rate of about 80%, and long-term cumulative results over three years of about 70%.

The complete femoral bypass operation that Dr. Laufman has presented is an excellent procedure in selected cases. Since the end-to-side anastomosis that this technique requires both proximally and distally is hemodynamically somewhat less effcient than end-to-end anastomosis, we in general prefer techniques employing the latter. In some situations, however, the bypass operation is the procedure of choice, since it spares important collaterals that would be destroyed or imperiled by procedures utilizing end-to-end anastomosis with transection of the femoral trunk. We think, however, that it is more physiological and safer to place the bypass graft deep to the sartorius, even though this requires a small amount of added dissection.

DR. JOSEPHUS C. LUKE, Montreal, Canada: May I present our experience with this end-to-side bypass technique. Since June, 1955, we have done 14 segmental occlusions of the femoral artery by this method. All were done for intermittent claudication in the calf. One graft closed four weeks after operation, but the remainder to date have maintained a pedal pulse. Prior to June we were doing end-to-end anastomoses and our failure rate was about 50%; so I think we can say with assurance that the end-to-side technique has markedly improved this operation.

I should also like to mention seven other cases where this technique has been carried to an extreme degree in an effort to obviate a supracondylar amputation. All seven had severely ischemic feet with areas of gangrene on toes or heel which had not responded to conservative therapy. Arteriograms on these people reveal, in each case, occlusion of the profunda branch with a segmental occlusion of the femoral. The patent vessels showed marked arteriosclerosis. End-to-side bypass homografts were placed about the occluded femoral segment. Initially, in every case, the foot circulation was markedly improved with disappearance of the foot pain and increase in temperature. However, one graft occluded in eight days and one in three weeks with resulting above-knee amputation. The other five have warm feet but no return of distal pulses, and have now a good viable leg. Local toe amputations were done in two cases at time of grafting, and in the others the gangrenous spots have demarcated and healed or are healing.

DR. JOHN J. CRANLEY, Cincinnati: I should like to second the plea of Dr. Eiseman that the diagnosis of obliterative arterial disease, or of aortic aneurysm, is in itself not an indication for operation.

In regard to the lower extremity, a vast difference exists between arterial insufficiency of muscle and arterial insufficiency of skin. Although this may be only quantitative, it is of great clinical importance because there must be thousands, possibly millions, of people in the older age group who have intermittent claudication but who are in no danger of losing their legs. Intermittent claudication establishes the diagnosis of obliterative

arterial disease but is, in itself, never an indication for an amputation. Therefore, the need of the patient to improve his walking ability must be considered before subjecting him to an operative procedure.

Another point to be remembered is that the disease is not always progressive clinically, even though it may be considered progressive from a pathological point of view. This is because the clinician is interested in the total circulation of the extremity, and if the collateral circulation is able to compensate for the occlusion of the major artery, the limb is in no danger of developing ischemic necrosis.

After one has decided that insertion of an arterial graft is desirable, an arteriogram is indicated to determine whether or not a good outflow tract exists.

In regard to aneurysms, two years ago Dr. Herrmann and I presented a paper before this association on the Natural History of Aortic Aneurysms. The unpleasant fact is that when we analyzed every single case of aneurysm of the abdominal aorta due to arteriosclerosis found at autopsy during a 25-year period at the Cincinnati General Hospital, only 25% of these patients died of their aneurysm. However, our observations suggest that once a patient with an aortic aneurysm developed symptoms, operation is indicated.

DR. JOHN HURST OLWIN, Chicago: I should like to congratulate Dr. Laufman and his associates on a very fine presentation. I should like to tell you briefly about one case that illustrates perhaps four principles involving this technique. One is that you can use a bypass technique on patients with rather severe atherosclerosis.

The second is the importance of allowing enough time from the initial injection of dye to fill the possibly open lower segments; the third is the possibility of using this technique in the presence of rather severe gangrene of the foot with salvage of the extremity, and, fourth, the possibility or even necessity of improvising in the way of grafts. These are the four principles.

Nine days ago we operated on a man 61 years of age with a block of both common iliac arteries, with gangrene of his foot with pain requiring narcotics, and these not being too successful in relieving the pain. We used a child's aorta from the common iliac, leading it down through the femoral canal and then using a segment of his own saphenous vein, reversed, of course, to bring the graft down to the popliteal artery.

[Slide] This shows the block of both iliac arteries. You can see an extreme degree of atherosclerosis in this whole area. You can see that the profunda is involved here, and not involved very much in this other area.

[Slide] This slide shows the atherosclerosis with the profunda showing here, and none of the collaterals. You can just begin to see an open segment here.

[Slide] Here you see a better showing of the segment, with the channels showing up here.

This patient's pain was relieved as soon as he was awake after the anesthesia. Pulses were present in his foot, and the large area of gangrenous ulcer on the dorsum of his foot after seven days of observation has narrowed to about one-half, and it looks as though he is going to be able to keep his foot. Five weeks after surgery the gangrene had healed, and the leg and foot were symptoms-free.

DR. HAROLD LAUFMAN, Chicago: I should like to thank all of the discussants for their kind remarks.

The percentage of suitable patients for bypass surgery is considerably less than the percentage of patients with proved segmental occlusions. I won't go into the contraindications as we have established them, but they will appear in the final paper.

Whereas some 75% of all the patients we arteriographed showed segmental occlusions, actually we do not operate on more than 50%. Sometimes there are indications for one procedure in one leg and another procedure in the other leg. We have had patients in whom one leg is suitable for sympathectomy, if anything, and the other leg suitable for bypass.

Long-term follow-up, of course, is of the utmost importance. We must find out what happens to these patients, as compared with patients either unoperated on or subjected to other procedures.

General sclerosis is not in itself the reason for creating a good vascular channel in the leg. Many patients with general sclerosis but with complete occlusion in a leg can be rehabilitated by giving them a good leg, provided there are no other medical contraindications.

The important thing that should be stressed is that the bypass graft carries with it no risk to limb and no risk to life, in our experience. You will notice that all of our patients have well-established collaterals, so that by the time they are operated on all the collaterals they are going to establish by themselves have been established already, and we must give them some help.

Equine Arterial Heterografts Altered by Controlled Enzymatic Digestion

A Preliminary Report

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and
HARVEY R. BUTCHER Jr., M.D., St. Louis

The inability to acquire satisfactory numbers of arterial homografts continues to spur the search for an adequate substitute. Such a substitute should possess the qualities of homografts which make them suitable for the correction of arterial aneurysms and occlusions. The ease of procuring animal arteries having a structure and distensibility similar to those of human arteries naturally has led to their consideration as vascular grafts. Carrel [1] first demonstrated the feasibility of using heterografts to bridge arterial defects in animals. However, in general, arterial heterotransplantation has been less successful than homotransplantation. This difference may be related, at least in part, to an immune response by the host. This investigation is an attempt to discover a method of altering animal arteries which will reduce the severity of the host's immune response to them without significant alteration of their structural integrity.

This is a preliminary report concerning the effect of controlled enzymatic digestions of equine carotid arteries upon their functionality from the standpoints of their distensibility and antigenicity. Horse carotid arteries were used because of their size, uniform caliber, length, paucity of branches, and their rich elastic tissue network.

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From the Department of Surgery, Washington University School of Medicine; Markle Scholar (Dr. Butcher).

Methods

A. Methods of Enzymatic Digestion.—The techniques of the digestions of equine arterial tissue with pepsin, trypsin, and papain were as follows:

1. Pepsin*: The filtrates of horse artery homogenates used in the serologic reactions shown in Table 2A were partially digested by incubating a 1:1 mixture of the filtrate and a 0.1% suspension of crystalline pepsin for three hours at 37 C in aminoacetic acid-HCl buffer (pH 2.0, ionic strength 0.07). The reaction was stopped by dilution with sodium bicarbonate to pH 7.6. Intact arteries were digested in 0.1% pepsin suspension in a variety of buffers. For the serologic reactions shown in Table 2B, arterial segments were digested in aminoacetic acid-HCl as above or in a mixture of KCl and HCl at pH 2.0 with ionic strength of 0.1. The latter method was used to study the relationship of time and temperature to the amount of digestion of arterial tissue.

2. Trypsin: A 0.1% suspension of crystalline trypsin in citrate-phosphate buffer (pH 7.8) was used to digest both the filtrates and the whole artery tissue.

3. Papain: A 0.1% suspension of crystalline papain in citrate-phosphate buffer (pH 6.0) was brought to a final concentration of 0.02 M KCN for activation of the enzyme. Both arterial filtrates and arterial segments were digested with this preparation.

The proteolytic activity of pepsin was determined by the hemoglobin digestion method described by Northrup.[2] The amount of total nitrogen digested from weighed amounts of arterial substrate was measured in the supernatant at intervals during

* Obtained from Worthington Biochemical Corporation, Freehold, N. J., Lots No. PM-594 and PM-596.

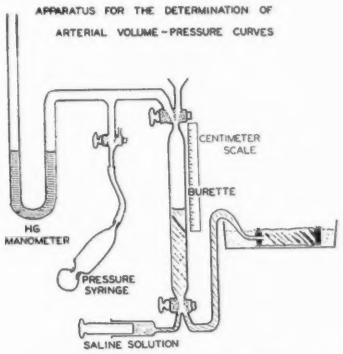

Fig. 1.—This diagram shows the modified Hallock-Benson apparatus used to measure the volume-pressure curves of arterial test segments. Elevation of the test artery above the lower end of the burette allows determination of volumes at near atmospheric intraluminal pressures.

tors used to connect the segment to the apparatus were tied in place prior to measuring the control value and were not disturbed until after the final measurements were made. This eliminated many variables present in the comparison of the values of different arterial segments. The volume-distensibility coefficient at 25 mm.Hg intervals of intraluminal pressure was calculated by the formula of Bramwell and Hill †:

$$D_x = \frac{100}{V} \times \frac{dv}{dp}$$

D_x is the distensibility expressed as per cent increase or decrease in volume per millimeter Hg change in pressure at x mm.Hg intraluminal pressure; V, the volume of the arterial segment at x mm.Hg intraluminal pressure, and dv the change in volume associated with dp, the change in pressure; dv and dp were measured by drawing a tangent at the x mm.Hg point on the volume-pressure curve (Fig. 2). All comparisons of

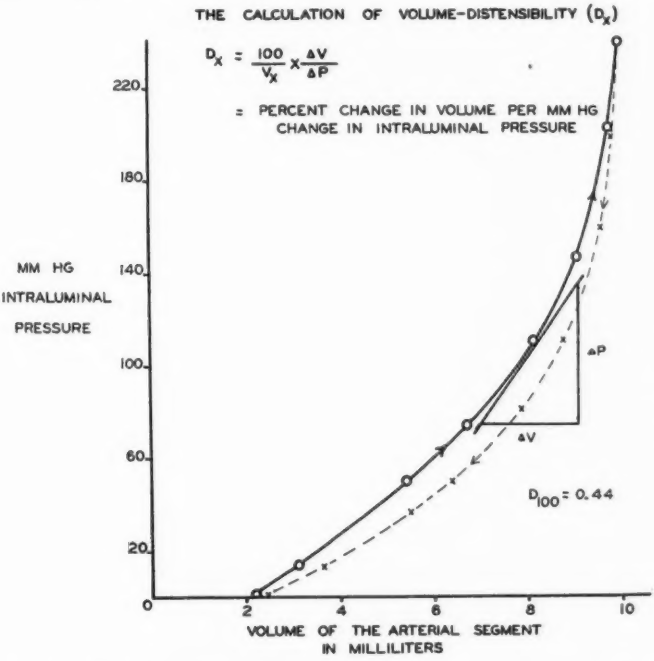

Fig. 2.—The graph is a plot of the volume with stepwise increases (o—o) and decreases (x---x) of intraluminal pressure. The formula shown above was used to calculate the volume-distensibility coefficients at 25 mm. Hg intervals of pressure.

digestion by the Kjeldahl technique.

Tissue sections of arteries treated by various methods of digestion were studied microscopically.

B. Arterial Distensibility.—The volume of arterial segments and their distensibility per unit change in intraluminal pressure was measured with use of a modification of the Hallock and Benson apparatus[6] (Fig. 1). Each arterial segment served as its own control. The plastic adap-

volume-distensibility before and after digestion were made upon volume-pressure curves stabilized by five or six stepwise increases and decreases of intraluminal pressure.[6]

C. Immunologic Methods.—The Freund adjuvant technique ‡ was used to produce rabbit serum

† References 7 and 8.

‡ References 3 and 4.

antibodies to horse carotid artery tissue. The semiquantitative techniques of Kolmer were used in these preliminary studies to estimate antigenic specificity.

The filtrates of horse carotid artery homogenates were prepared by homogenizing segments of several arteries in a Virtis 45 homogenizer at 0 C, then filtering the homogenate. The total nitrogen content of the filtrates was measured with the use of modifications of the microdiffusion technique of Conway.[5] All dilutions of the filtrates were made with a 0.15 N saline solution.

Results

A. Enzymatic Digestions.—No characteristic gross or microscopic changes in the arteries attended their limited digestion with a particular enzyme. Edema of the adventitia and intima and partial destruction of smooth muscle cellular architecture was observed with all types of enzymatic digestion. Only minimal fragmentation of the elastic tissue network was present following digestions limited to three hours at 37 C. The exposure of arteries to pepsin for 48 hours at 5 C and then two hours at 37 C produced similar histologic changes.

Initial immunologic studies (Table 2A) showed an alteration in antigenicity of the arterial proteins only after digestion with pepsin. Therefore, further study of the effect of digestion with papain and trypsin was deferred.

The relationship of time to the amount of peptic digestion of the arterial wall at 5 C and 37 C is shown in Table 1 and Figure 3. Although some nitrogen was digested from the arterial tissue at the lower temperature, the rate of its removal was greatly accelerated when the temperature was elevated to 37 C.

The volume-distensibility coefficient at 25 mm.Hg increments of intraluminal pressure tended to increase after digestion except in the 75-100 mm.Hg pressure range. In other words, peptic digestion tends to weaken the arterial wall. Digestion of an arterial segment with pepsin for three or more hours at 37 C produces a slight but consistent increase in its distensibility at the higher intraluminal pressures. An example of digestion of an artery with pepsin

TABLE 1.—*The Extent of Digestion of Five-Centimeter Segments of Horse Carotid Artery with Pepsin (0.1%)**

Duration of Digestion, Hr.	Sample Number	Wet Weight of Artery, Gm.	Total Tissue Nitrogen After Digestion, Mg.	Nitrogen Released by Digestion, Mg.†	Total Tissue Nitrogen, %	Nitrogen Released per Gram of Artery, Mg.
A. Digestion at 5 C						
6	1	2.71	71.59	3.73	5.0	1.4
	2	2.37	52.46	3.03	5.5	1.3
	3	1.64	....	2.89	....	1.8
12	1	2.93	91.38	6.86	7.0	2.3
	2	1.85	54.82	4.99	8.3	2.7
24	1	2.27	62.40	7.04	10.0	3.1
	2	2.65	73.76	9.78	11.7	4.1
	3	1.92	....	7.26	....	3.8
48	1	2.51	46.37	10.69	18.8	4.3
	2	3.26	99.17	12.93	11.5	4.0
	3	2.21	....	11.66	....	5.3
72	1	3.36	94.47	15.04	13.7	4.5
	2	2.31	44.98	15.93	26.2	6.9
	3	2.12	47.64	17.04	26.4	8.0
B. Digestion at 37 C after 48 hr. of digestion at 5 C						
1	1	2.75	52.25	19.75	27.5	7.2
2	1	3.07	78.80	30.83	28.2	10.0
	2	2.76	43.72	29.84	40.6	10.8
	3	1.97	36.24	36.46	50.1	18.5

* Worthington Biochemical Corporation, Lot No. PM 596, 50 ml. of suspension containing 4.5 units per liter.
† Pepsin nitrogen (7.69 mg. in each digestion) has been subtracted from the nitrogen content of the digest.

TABLE 2.—*The Extent of Complement Fixation by Equine Artery Antigen Preparations*

Antigen*	Equine Artery Antiserum, †Ml. in the Reaction					Control	
	0.2	0.1	0.05	0.025	0.005	Serum	Antigen
A. Filtrates of equine artery homogenates							
1. Undigested	4‡	4	4	3	0	0	0
2. Digested with							
(a) Papain 0.1%, 37 C for 3 hr., pH 6.0 in 0.02 M KCN	4	4	4	3	0	0	0
(b) Trypsin at 37 C, 3 hr., pH 7.4	4	4	4	3	0	0	
(c) Aminoacetic acid buffer alone, 37 C, 3 hr.	4	4	4	3	0	0	
(d) Pepsin, 37 C, for 3 hr. in aminoacetic acid-HCl buffer, pH 2	0	0	0	0	0	0	0
B. Filtrates of homogenates made after digestion of equine arteries with							
1. (a) Papain, 5 C, for 6 days, pH 6.0 in 0.02 M KCN	4	4	3	0	0	0	0
(b) Trypsin, 3 hr. at 37 C, pH 7.4	4	4	4	0	0	0	0
(c) Pepsin, 37 C, for 3 hr., pH 3	4	4	4	3	0	0	0
(d) Pepsin, 5 C, pH 3, for 6 days, then 3 hr. at 37 C	0	0	0	0	0	0	0
2. Undigested	4	4	4	3	0	0	0

* Ten micrograms of antigen were used in each reaction.
† The equine artery antiserum was made in rabbits by use of the Freund technique.
‡ The numbers 0-4 indicate the extent of complement fixation.

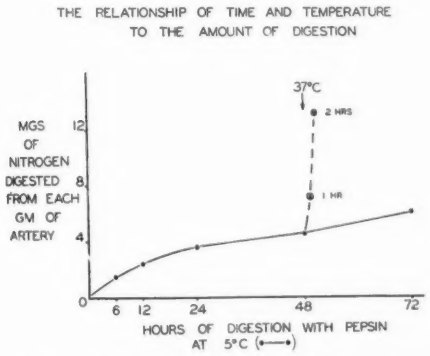

Fig. 3.—The rate of digestion of artery tissue with 0.1% pepsin was very slow when performed at 5 C (o—o), but proceeded much faster at 37 C (x - - -x).

for six hours is shown in Figure 4. Digestion of arterial segments with pepsin for 48 hours at 5 C and 2 hours at 37 C produced minimal changes in the volumes of test segments and in their volume-distensibility coefficients at the higher intraluminal pressures (Fig. 5).

B. Immunologic Studies.—In the preliminary experiments, filtrates of fresh equine artery homogenates were repeatedly injected subcutaneously into rabbits in saline suspension. The simple saline suspension of fresh artery was incapable of inducing demonstrable antibody titers in rabbits. However, two subcutaneous injections of the filtrates of arterial homogenates in a water-in-oil emulsion with heat-killed Mycobacterium butyricum at three-week intervals (the Freund technique) regularly produced satisfactory antibody titers (Table 2).

Complement-fixation reactions using the equine artery antiserum prepared in rabbits showed that digestion of the filtrate of the homogenate of fresh artery with pepsin (0.1%) for three hours at 37 C altered the filtrate sufficiently to prevent its reaction with the horse artery complement-fixing antibodies. However, similar partial digestion of this filtrate with papain (0.1%), trypsin (0.1%), or acid buffer (aminoacetic acid-HCl, pH 2.0) did not measurably effect the serologic specificity of the filtrate (Table 2A). Antigen controls showed that this failure was not due to inhibition of complement fixation by citrate-phosphate buffer.

The digestion for three hours at 37 C of intact arterial segments with 0.1% suspensions of pepsin, trypsin, and papain before their homogenization and filtration did not prevent the resulting filtrates from reacting with the horse artery complement-fixing antibodies. However, the filtrate prepared from arteries digested with pepsin (0.1%)

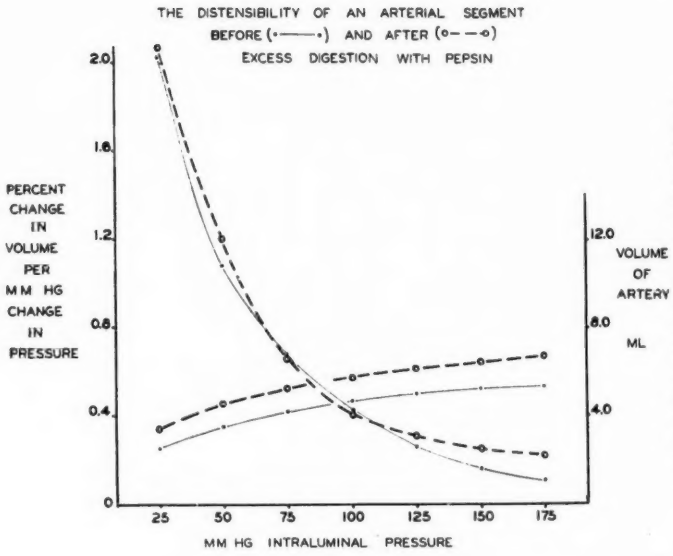

Fig. 4.—The rising volume-distensibility coefficients at intervals of 25 mm Hg intraluminal pressure are greater after digestion with 0.1% pepsin for six hours at 37 C than before it, except at the 75 and 100 mm.Hg intraluminal pressures. The postdigestion volumes are also increased. Similar increases in these values at the higher intraluminal pressure are seen after three or more hours of peptic digestion at 37 C.

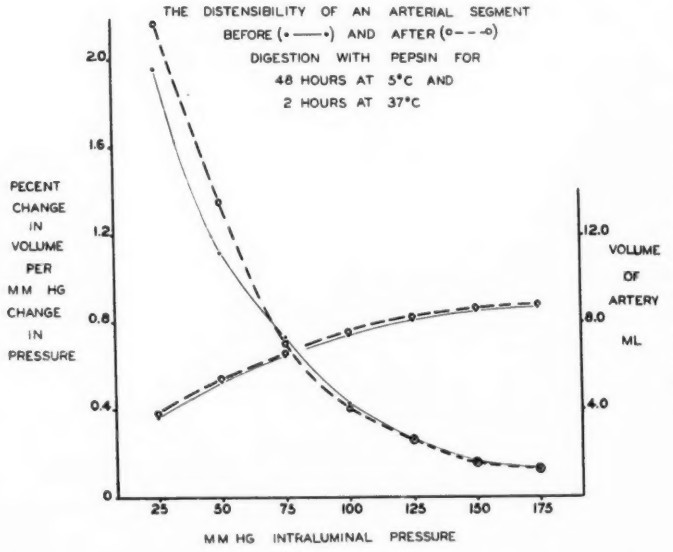

Fig. 5.—Minimal differences in the volumes and the rising volume-distensibility coefficients are seen before and after peptic digestion of a test artery for 48 hours at 5 C and 2 hours at 37 C. Significant increases in distensibility are shown only at the lower intraluminal pressures.

for six days at 5 C and three hours at 37 C no longer combined with the equine artery antibodies. Presumptively, preliminary exposure of artery to pepsin for six days before active digestion permitted sufficient diffusion of the pepsin through the arterial wall to allow the active digestion to change the antigenic specificity of the soluble proteins. Contrariwise, the filtrate of the arteries predigested with papain for six days at 5 C still combined well with horse artery antibodies (Table 2B).

Whether or not partial peptic digestion of intact arterial tissue decreases its antigenicity is under investigation, although it is realized that the study of systems of

multiple unknown antigens is subject to many errors.

Comment

Permanent homotransplantation of human tissue is unsuccessful except the donor and recipient be identical twins or possibly the graft be corneal. Thus, the clinical success of most homografts depends on their acting as an adequate temporary scaffold on which the host may build (homografts of bone and artery), or as a temporary substitute (cutaneous homografts or the red blood cell transfusion). The red blood cell transfusion is the type of homotransplantation that has been most intensively studied immunologically. The red blood cell has been shown to contain many distinct antigens, few of which are of general clinical importance. Though the A, B, O factors and the C, D, E group may be controlled, the chance of administering a theoretically compatible transfusion is very small. The clinical success of this "graft" would seem dependent upon (1) the weakness of many of the antigens involved and (2) their relatively rapid elimination from the host.

Of the many means by which the antigenicity of proteins may be weakened, most must be discarded as too traumatic to the elastic tissue network for use in arteries. This does not appear to be the case with controlled peptic proteolysis. The results shown in Table 2 indicate that, of the proteolytic enzymes studied, pepsin is the most capable of destroying antigenic specificity of the soluble proteins of the arterial wall. Weil and co-workers [10] produced a similar change in diphtheria antitoxin by its partial digestion with pepsin. They not only altered its antigenic specificity but showed that pepsin made the antitoxin a weaker antigen without destroying its antitoxic capabilities. Partial peptic proteolysis probably brings about these changes (1) by splitting off antigenic side-groups from the protein and (2) by reducing the protein molecular size, which allows its more rapid elimination by the host. In intact tissues, more rapid elimination of antigens probably follows the break-down of cell membranes and intercellular matrix. Such changes are seen microscopically in the tissue sections of arteries after their partial peptic digestion.

The elimination of the proteins of the arterial wall should not influence the ultimate outcome of the graft if their rate of removal is not too rapid and the elastic tissue network remains intact. Although the rate of peptic digestion of elastin is very slow,[11] the removal of other enzymatically altered protein structures from the artery wall by the host before their adequate replacement may cause early aneurysm formation. Obviously, if digestion of animal arteries is carried too far, early aneurysms can be expected. This error may be avoided, at least in part, by measurements of arterial distensibility. Digestions for three or more hours at 37 C appear to increase the distensibility of the artery at intraluminal pressures above 100 mm.Hg (Fig. 4). Although such weakening of the artery wall may be avoided in the preparation of the heterograft, the possibility of too rapid a removal of the nonelastic structural components of the artery still remains as a possible source of aneurysm. Whether or not late aneurysms will develop in pepsin-treated heterografts is as yet unknown.

The early results of transplantation of equine heterografts treated by controlled peptic digestion into animals have been sufficiently encouraging to warrant their use for the reconstitution of obliterated femoral arteries in patients critically in need of peripheral blood flow improvement. The results of their trial in animals and man will be presented in detail in a future publication. However, caution in the clinical use of animal arteries partially digested with pepsin needs to be stressed. A case in point follows:

A 59-year-old white woman entered the Barnes Hospital in September, 1955, because of intermittent claudication in the left leg which had increased in severity over the previous four years and had been associated with rest pain, coldness, atrophy, and severe weakness for the previous year. Previous therapy with tolazoline (Priscoline), intra-arterial histamine, and diathermy was

without benefit. Femoral arteriograms showed occlusion of the left superficial femoral artery.

Because of lack of a satisfactory arterial homograft, the patient was discharged. The continued severity of symptoms caused her readmission in November, 1955. On Dec. 7, 1955, a shunting heterograft was placed in the left leg from the external iliac artery to the midportion of the popliteal artery. The heterograft used was equine carotid artery which had been proteolyzed with pepsin (0.1%) for four hours at 37 C. There was marked improvement in the peripheral blood flow after insertion of the heterograft. Twelve days postoperatively, sudden onset of pain and moderate swelling was noted over the graft. A small hemorrhage from the graft was postulated to explain this episode. The pain and swelling soon subsided. However, she required replacement of the digested equine heterograft in February, 1956, because of the formation of aneurysms in it (Fig. 6).

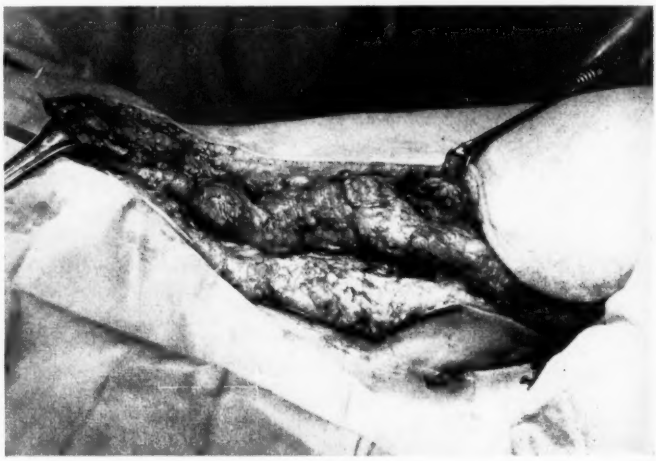

Fig. 6.—Multiple aneurysms in an equine carotid heterograft two months after it had been digested with 0.1% pepsin for four hours at 37 C and used to shunt an obliterated superficial femoral artery.

Tissue sections of the removed heterograft showed localized areas of infiltration of plasma cells and eosinophiles and other areas of large collections of epitheloid macrophages around giant cells. The first of these microscopic changes is compatible with a circulating antibody type of response, while the latter suggests a response similar to tuberculin hypersensitivity. Although excess digestion may have been the cause of aneurysm formation in this heterograft, the possibility exists that an immune response played a role.

Summary

A preliminary study of the effect of partial enzymatic digestions with pepsin, papain, and trypsin upon the antigenicity and distensibility of equine carotid arteries showed the following results:

1. Controlled peptic digestion changes the antigenic specificity of the soluble proteins of the artery wall. Similar digestion with papain and trypsin does not.

2. The arterial wall is weakened by digestion with pepsin (0.1%) exceeding three hours at 37 C.

3. Aneurysm formation may follow the use of pepsin-treated heterografts in man.

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Observations of Elastic Synthetic Fabric Sleeves as Vascular Prostheses

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There is a best way to do everything
—Emerson

Review of the many published reports * dealing with the investigation of plastic fabrics as vascular prostheses has led to a reappraisal of the problem in this laboratory. In those reports, although much importance has been attached to the facility with which various synthetic tubes maintain blood flow, little attention has been given to several very important aspects of the basic problem of converting commercially prepared cloth fabrics into physiologically sound and surgically acceptable substitutes for vascular segments. Great interest has been evident in comparative rates of "endothelial" regrowth, for instance, but only one observer is on record as having attached any significance to the need for some degree of elasticity in the prosthetic grafts.[19] Problems of wrinkling and thrombosis have been discussed, but several investigators seem prepared to accept and have, in fact, already put to clinical use, fabrics having an inherent tendency to such complications. Likewise, the impossibility of performing acceptable anastomoses with many of the commercial fabrics has been largely disregarded.

Discussing what he terms "the reservoir function of the central arteries," Wiggers[20] has called attention to the compression chamber effect of the distensible aorta and its immediate branches. By virtue of their elastic walls, the vessels store nearly half of the stroke volume of the left ventricle during systole. During diastole this blood is moved on by elastic recoil. Thus, variations in pressure and flow tend to be buffered to some extent. It is suspected that this provides the end-organ with a more constant perfusion rate and also has a sparing action on the central organ—the heart.

Because this laboratory was already engaged in a general program involving the application of synthetic materials as endoprosthetics, attention was focused upon the desirability of simulating, as nearly as possible, all attributes of segments to be replaced. With these ideas in mind the present studies were initiated. Consideration of the importance of the distensibility of arteries led to an investigation of elastic synthetic seamless sleeves. To date, 14 fabrics have been tested by methods to be described. Evaluation of these fabrics, both elastic and inelastic, forms the substance of this preliminary report.

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* References 1-18.

Method

Seventy-four adult mongrel dogs have been subjected to replacement of a portion of either thoracic or abdominal aorta by synthetic fabric sleeves. The animals are anesthetized by intravenous veterinary pentobarbital (Nembutal), 12 mg. per pound of body weight. The entire operative area is shaved, after which an endotracheal catheter is placed and a large-bore needle is introduced into a hind leg vein for administration of supportive fluids. The thoracic cavity is entered through the bed of the removed left sixth rib; the abdomen, through a midline incision. The aorta is cleaned of pleura or peritoneum, from subclavian artery to diaphragm, or from renal arteries to the trifurcation. Involved pairs of intercostal or lumbar arteries are transected between ligatures. From 4 to 8 cm. of aorta is then removed between Potts ductus clamps. For thoracic aortic replacement, the test graft material, previously preclotted with host blood, is placed over a tubular polyethylene shunt (Fig. 1). This shunt proximally. This use of a shunt, as suggested by Johnson,[21] has eliminated the need of cumbersome hypothermia techniques. In the abdominal aorta the polyethylene shunt can be omitted. The preliminary infusion of 5% dextrose and water is changed to whole blood during the period of clamp release, and blood loss can be quickly replaced. Where possible, the grafted segment of aorta is recovered with parietal membrane, and the body wall is closed in accepted fashion. Procaine penicillin G (Depo-Penicillin), 600,000 units, is given intramuscularly at the conclusion of the procedure.

After varying periods of observation, during which time aortograms have been made in some instances, the animals are reanesthetized. The graft area is inspected, and the amount of pulsation within the graft is noted. The fabric graft and sufficient length of aorta on either end is then removed en bloc and photographed. The internal surface is likewise inspected and photographed. Notation is made of the amount of intimal proliferation and the presence of any thrombus or

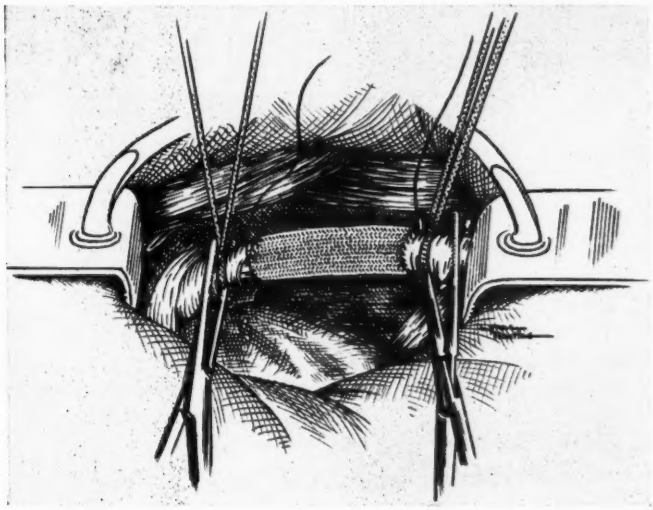

Fig. 1.—In replacement of portion of thoracic aorta, test graft is placed over polyethylene tube. Blood flow can then be reestablished during anastomosis. Just before distal anastomosis is complete, shunt is removed.

is quickly tied into the severed ends of the aorta by broad cotton tape ties. The Potts clamps are then opened, allowing perfusion of the abdominal aorta during the critical period of anastomosis. The graft is sutured to aorta above and below by 00000 nylon arterial sutures.† After three-quarters of the circumference of both suture lines is complete, Potts clamps are replaced, the polyethylene shunt is removed, and the remainder of each anastomosis is completed. The clamps are then finally removed judiciously, first distally and then kinking of the fabric, after which the specimen is fixed in Bouin's solution and prepared for microscopic examination.

Technique for Preparation of Tissue for Slides

Specimens were fixed in Bouin's solution for 48 hours. Sagittal blocks of tissue were taken through the proximal lines and the distal lines of anastomosis, and a transverse block was taken through the middle of the prosthesis area. These were washed in running water for 24 hours, dehydrated through alcohol, and placed in collo-

† Supplied by J. A. Deknatel and Sons, Inc.

dion for 24 hours. At the end of this period they were put through chloroform and toluene and then into paraffin at 60 F. Sections were made on a rotary microtome at 7μ; the face of the block was coated with paraffin before each cut. The sections were mounted directly on slides without using water. The preparations were stained with hematoxylin and eosin and with the Gomori aldehyde-fuchsin (elastic tissue) stain.

Results

All materials utilized, to date, are tabulated in the accompanying Tables. In general, the Tables themselves are explanatory. Observations were made regarding pertinent characteristics, and each material was arbitrarily classified as satisfactory, or unsatisfactory, on the basis of these criteria. Owing to the relatively short duration of these observations, the number of criteria, no doubt, will have to be extended in the future as long-term observations bring to light other factors of importance.

In general, seamless sleeves appear to serve more satisfactorily than hand-fashioned tubular conduits. As had been postulated, presence of the longitudinal seam appears to generate thrombosis. In Figure 2 is demonstrated such a graft in which clot piled up along the suture line. Although in this case the animal suffered no observed

TABLE 1.—*List of Synthetic Fabrics Utilized to Date, with Specifications*

Material Tested	Number of Animals	Duration Observation Min.-Max. Days	Thread Count /In.	Size of Interspace, μ	Availability as Seamless Tube	Elasticity	Excessive Bleeding (if Fabric is Untreated)
1. Nylon tricot No. 2008	4	96-113	140 × 80	10 × 80	No	Yes	Yes
2. Nylon knit No. 104	4	69-102	100 × 76	35 × 60	No	Yes	No
3. Nylon mil. No. 444	5	150-222	100 × 100	15 × 65	No	Yes	No
4. Orlon tricot No. 1009	2	76-164	96 × 72	25 × 55	No ?	Yes	Yes
5. Vinyon-N No. 614	3	0-96	140 × 100	30 × 60	No ?	Yes, no	Yes
6. Stehli No. 115	6	2-110	200 × 144	10 × 10	No	No	Yes
7. Nylon knit No. 14	7	58-134	76 × 56	20 × 75	Yes	No	No
8. Nylon braid No. 15	8	100-82	200 × 100	10 × 15	Yes	No	No
9. USCI heavy No. 112	3	78-89	100 × 100	15 × 25	Yes	No	No
10. Nylon crimped Seamless No. 302	9	80-135	40 × 20	20 × 30	Yes	No	Yes, no
11. Electra braid No. 87	2	28-200	48 × 48	35 × 40	Yes	No	No
12. USCI med. nylon No. 113	4	65-74	56 × 56	40 × 55	Yes	No	No
13. B-H Dacron No. 114	6	84-188	68 × 60	25 × 40	Yes	No	No
14. B-H Helanca No. 100606	12	1-156	100 × 100	10 × 40	Yes	Yes	Yes, no

TABLE 2.—*Analysis of Various Fabrics in Regard to Suitability as Vascular Prostheses*

Material Tested	Wrinkle	Thrombosis	Excessive Dilatation	Inner Lining	Outer Covering	Durability, Carcinogenicity	Excessive Foreign-Body Reaction
1. Nylon tricot No. 2008	No	Yes	Yes	Good	Fair	Time insufficient for observation	No
2. Nylon knit No. 104	No	Yes	Yes	Fair	Good		No
3. Nylon mil. No. 444	Yes	No	Yes	Good	Fair		No
4. Orlon tricot No. 1009	No	No	Yes	Fair	Good		No
5. Vinyon-N No. 614	No	No	Yes	Good	Excessive		Yes
6. Stehli No. 115	Yes	Yes	No	Good	Fair		No
7. Nylon knit No. 14	Yes	Yes	No	Poor	Good		No
8. Nylon braid No. 15	Yes	Yes	No	Fair	Poor		No
9. USCI heavy No. 112	No	Yes	No	Fair	Poor		No
10. Nylon crimped seamless No. 302	No	Yes	No	Good	Poor		No
11. Electra braid No. 87	Yes	No	No	Fair	Fair		No
12. USCI med. nylon No. 113	No	No	No	Fair	Good		No
13. B-H Dacron No. 114	Yes	No	No	Fair	Good		No
14. B-H Helanca No. 100606	No	No	No	Good	Good		No

ill effect, remaining vigorous, with strong femoral pulses until the time of killing, at 222 days, such a nidus for thrombosis is better eliminated.

Furthermore, hand-sewn grafts of commercial fabric selected for elasticity were found to develop aneurysmal dilatation. One of these prostheses is pictured in Figure 3. Here, endothelialization was almost complete, but the dilatation apparent in the postmortem specimen had been anticipated by an earlier aortogram (Fig. 4). In another specimen, similar dilatation was associated with early clot formation (Fig. 5). In consequence of these preliminary observations, attention was early turned to the use of seamless sleeves. Sources for such tubes manufactured of synthetic yarns were limited to three companies able to cooperate in these studies. Two other investigators also agreed to further testing of seamless grafts manufactured under their direction.‡

Such seamless tubes were either knitted or braided. Braided tubes tend to fray readily at the cut ends, whereas knitted tubes will unravel, or "run," if undue tension is applied at the end. While the turning of a cuff has been suggested widely, to offset these undesirable traits, such a cuff

‡ Dr. Paul Sanger, Charlotte, N. C.; Dr. W. Sterling Edwards, Birmingham, Ala.

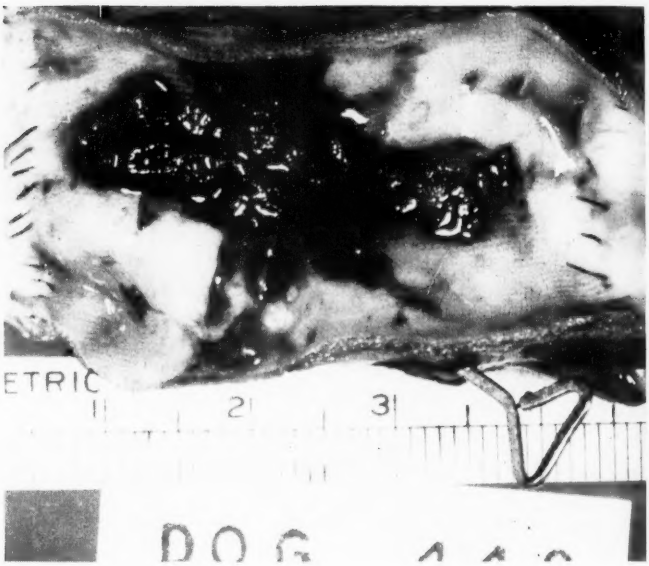

Fig. 2. — Hand-sewn woven nylon fabric graft, within which partial thrombosis had developed along longitudinal suture; 222 days.

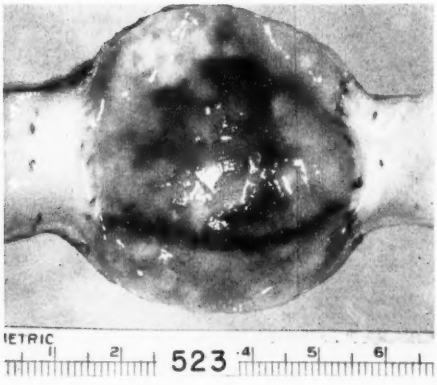

Fig. 3.—Hand-sewn elastic nylon fabric graft, several of which developed aneurysmal dilatation; 126 days.

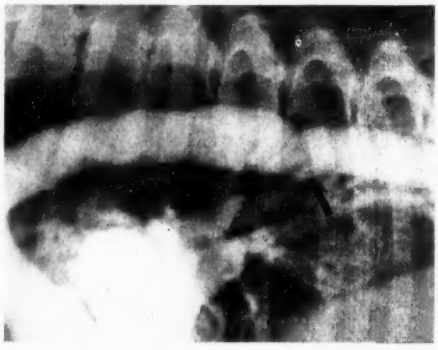

Fig. 4.—Aortogram representative of usual picture with hand-sewn elastic grafts; 60 days.

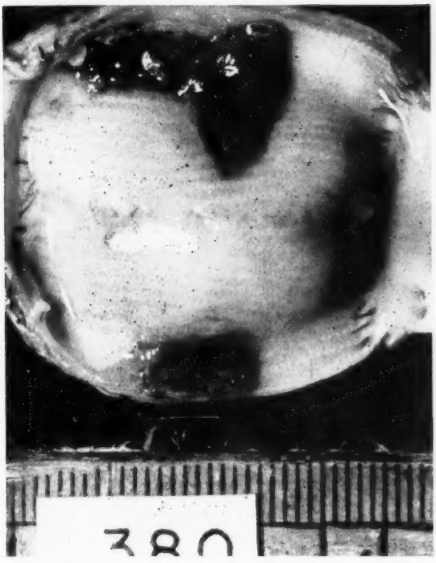

Fig. 5.—In some cases dilatation was associated with thrombosis apart from suture line; 92 days.

works a disadvantage because of further narrowing at the two already critical lines of anastomosis. Actually, most of these synthetic yarns have a rather low melting point. Careful application of a hot cautery wire, or even the direct flame, will fuse the fibers sufficiently to prohibit fraying, and a cuff becomes unnecessary.§

In Figure 6 is illustrated a tightly braided seamless nylon tube, of coarse yarn. This type of material was found unsatisfactory from the start because of the great difficulty encountered in suturing it. The resistance of the fabric rendered the usual small arterial needle useless. Furthermore, early thrombosis apparently resulted from the uneven nature of the internal surface.

Several seamless tubes developed severe wrinkles as they were sutured to the aorta. In Figure 7 is a graft made of tightly braided Dacron, which showed many such wrinkles. On the other hand, this fabric was lined quite smoothly inside and had a firmly attached fibrous sheath. Occasionally the wrinkle developed later, in the center of the graft (Fig. 8), and gave rise to a thrombus.

The crimped braided nylon tubes currently available, commercially, for peripheral arterial replacement were also found to be somewhat resistant to passage of su-

§ Personal communication to the authors from Mr. Norman C. Jeckel, U. S. Catheter and Instrument Company, Glens Falls, N. Y.

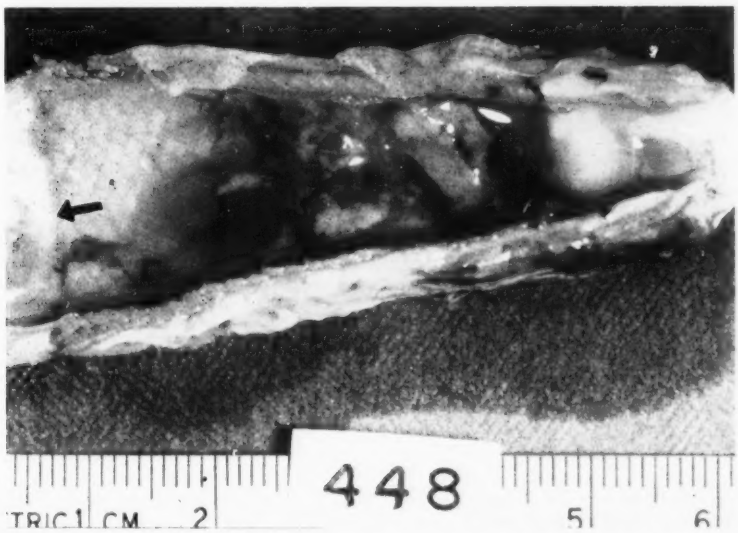

Fig. 6.—Heavy, coarse braided nylon seamless tubes developed thrombus and were difficult to suture. In this, a calcium plaque developed above proximal anatomosis; 141 days.

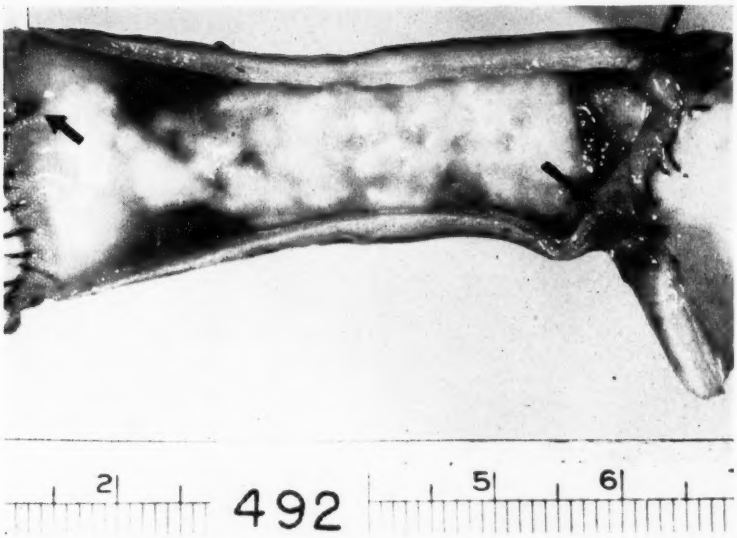

Fig. 7.—Several seamless tubes wrinkled badly at junction of graft and aorta; 135 days.

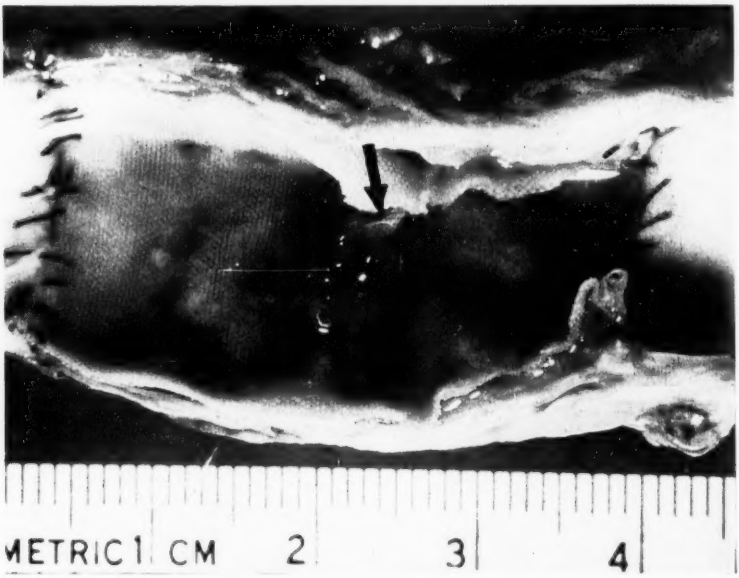

Fig. 8.—Here the wrinkle developed in the center of the graft, initiating thrombosis. This material resists ingrowth of fibrous tissue; 120 days.

ture needles. One of these specimens developed a smooth lining (Fig. 9), but the fibrous outer layer was poorly attached (Fig. 10). Another such graft developed a large hematoma outside and a complete occlusion at the distal suture line (Fig. 11).

The knitted seamless nylon grafts also sutured with difficulty, were completely in-

Fig. 9.—Crimped braided nylon tube developed good "intimal" lining but was difficult to suture; 128 days.

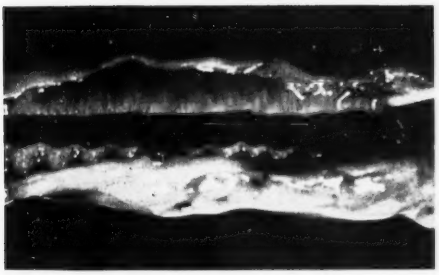

Fig. 10.—Crimped seamless tubes also resisted ingrowth of fibrous tissue; here, outer sheath peels readily; 128 days.

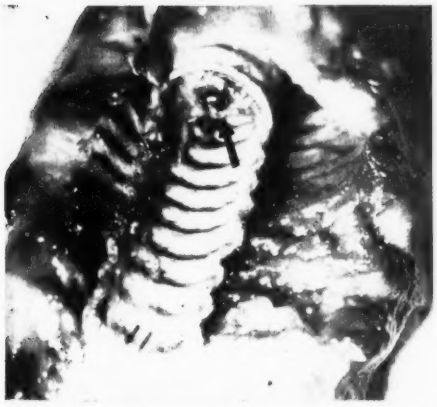

Fig. 11.—This crimped sleeve was surrounded by a large hematoma and was occluded by thrombus at distal suture line; 37 days.

Fig. 12.—Knitted nylon seamless sleeves were also difficult to suture, and some developed thrombus; 113 days.

elastic, and sometimes developed a thrombus (Fig. 12). With these, too, the outer capsule was not always firmly attached.

Finally, in Figures 13 to 20 are illustrated the elastic synthetic fabric seamless tubes which have been found most satisfactory, of the materials tested to date, in the course of these studies. This material only recently became available. Further refinement will certainly be necessary, but the fabric shows many desirable features. The texture of the braided material (Fig. 13) is soft and pliable. Some indication of its elasticity is shown in Figure 14, as a segment 1 cm. in diameter stretches over a cylinder 2 cm. in diameter. Similarly, this sleeve increases approximately one-third its length under moderate tension (25 lb.). A macrophotograph (Fig. 15) reveals the fluffy nature of the closely-braided curled threads. A microphotograph (Fig. 16) shows that elasticity is achieved by lengthening of the individual curled filaments of yarn as tension is increased.

The elastic seamless tubes have been braided from Helanca nylon yarn, which is the patented process thread used in the manufacture of the stretchable gloves, stockings, and undergarments in current vogue. It was first developed in Switzerland and is now manufactured in the United States by a limited number of mills. It is a multifilament yarn which gains its elasticity by a process of twisting or crimping the individual filaments before they are combined

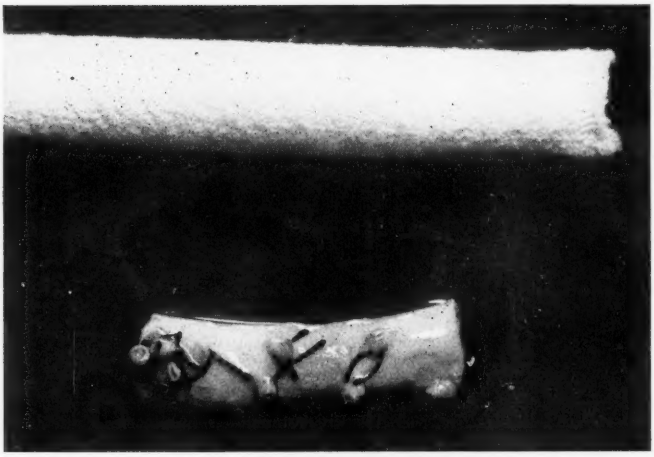

Fig. 13.—Helanca nylon braided seamless sleeve and section of dog aorta it replaces.

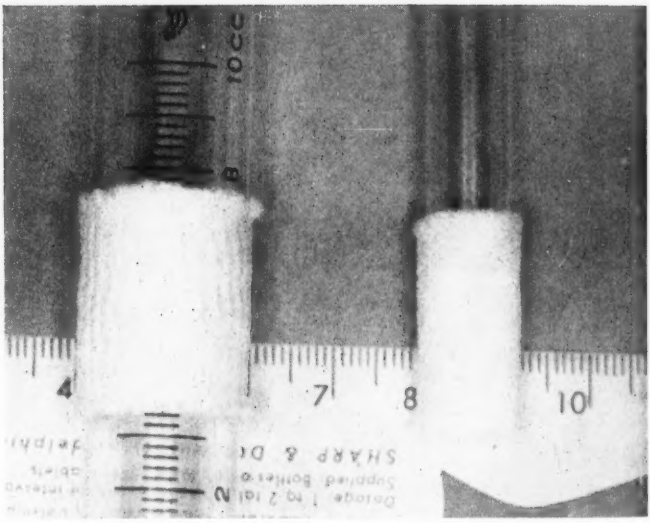

Fig. 14.—These synthetic tubes stretch readily.

into the finished yarn. Twisting induces curling, and this curl is set into the yarn by autoclaving.[‖]

The appearance of the distensible tube immediately after placement in a dog is shown in Figure 17. The external appearance of a reconstituted graft after 79 days is illustrated in Figure 18. The internal appearance of an early graft is seen in Figure 19, where already development of "intima" is complete at the ends and under way in the center.

‖ References 22 and 23.

Comment

One consistent criticism of several materials available, both as seamless sleeves and as sheet fabric, as mentioned, is the resistance of the cloth to the passage of even the small, Atraumatic arterial suture. On the other hand, the soft, permeable consistency of the elastic nylon fabric allows easy passage of the arterial needle and permits the use of small bites so that more accurate coaptation of vessel and prosthesis is accomplished. In the long run, this will inevitably provide less constriction, less

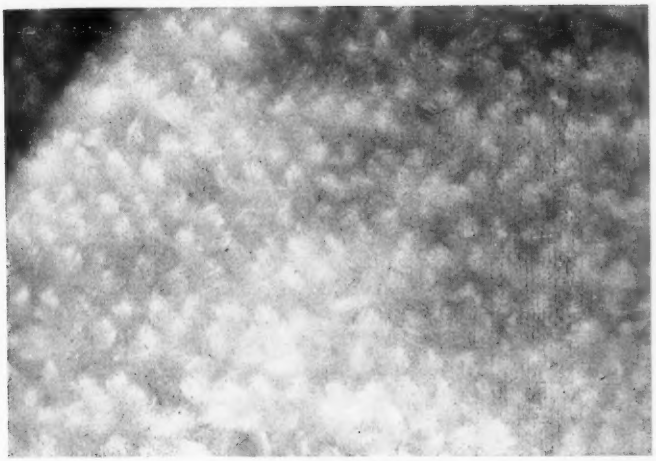

Fig. 15.—Macrophotograph of pliable, curly elastic nylon fabric.

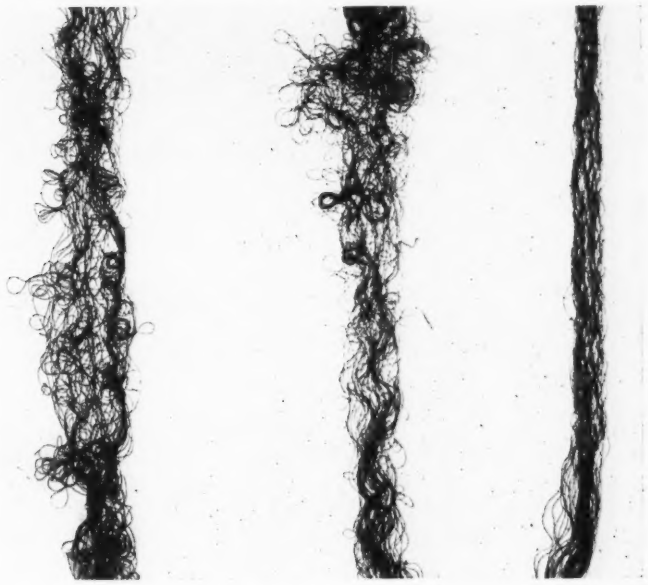

Fig. 16.—Microphotograph reveals nature of "elasticity."

thrombosis, and better end-result. Slight heat fusion of the cut end of this material renders use of a cuff completely unnecessary. Although severe bleeding may occur through the untreated fabric, hemorrhage can be controlled. Studies are presently underway to determine whether application of silicone film [21] will offer any advantage over simple preclotting, which has been very effective in eliminating loss of blood through the mesh. Tighter braiding, also, has been requested from the manufacturer,¶ but it is not clear, as yet, whether this will reduce the desired elasticity.

While it seems clear that maintenance of distensibility is a desirable goal, there is no certainty, as yet, that the Helanca seamless sleeves will maintain this quality in vivo. Preliminary observations show that the

¶ Bentley, Harris Manufacturing Company, Conshohocken, Pa.

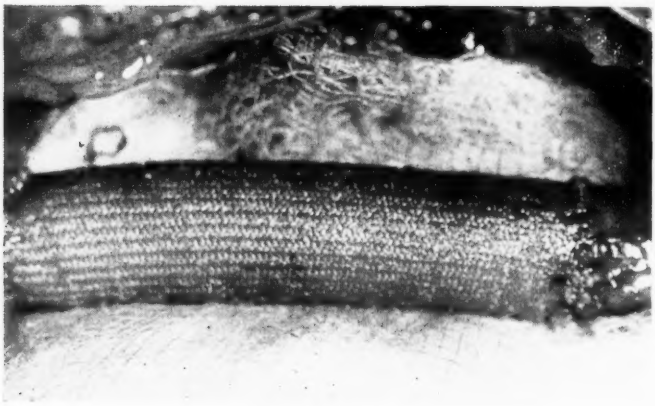

Fig. 17. — Appearance of preclotted distensible aortic prosthesis. Anastomosis just completed and blood flow reestablished.

Fig. 18.—External appearance of reconstituted "aorta" about a Helanca nylon prosthesis; 79 days.

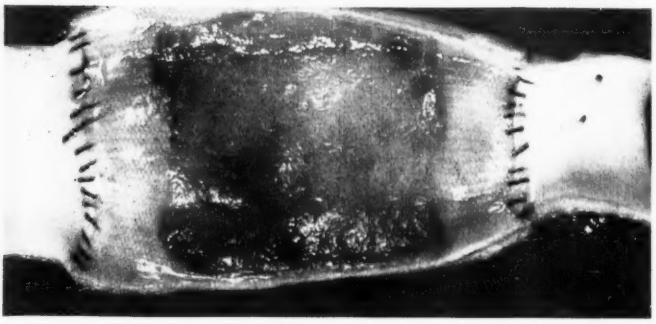

Fig. 19.—At 79 days, internal surface has begun to line with smooth, glistening membrane, similar to intima. This appears to extend onto prosthesis from aorta. In other specimens, however, it was apparent that internal lining may also develop from islands of fibrous tissue which grow within the mesh.

grafts did remain distensible for 150 days, even with moderate fibrous tissue about them. In the future perfection of elastic seamless synthetic fabrics as vascular prosthetics, it will be highly desirable to obtain comparative measurements of Helanca yarn elasticity as it relates to elasticity of the aortic wall. For many years physiologists have discussed the best method of assessing the elastic properties of the aorta and its branches.# In general, attention has been focused upon the changes of volume of a given segment of vessel which result from variations of internal pressures. This appears to be the most functionally appropriate method of evaluation. The ratio of pressure increase to percentage change in volume provides a volume-elasticity coefficient, and substances can then be compared

References 25-27.

Fig. 20. — Microscopic appearance of cross section of reconstituted aortic wall. Modified fibrous tissue lines luminal surface above. In center are fragments of nylon yarn. Below is fibrous tissue which coats prosthesis, taking the place of adventitia.

directly by these coefficients of elasticity.[28] However, since the pervious fabric graft does not lend itself immediately to measurement of volume, and because the introduction of any impervious lining would alter its coefficient, it is necessary to await complete vascular restitution of the prosthesis before such determinations will be reliable. The coefficient of elasticity of the reconstituted vessel can then be measured at various intervals to determine whether it changes with age as does that of normal vessels of man and animal.[29]

Preliminary microscopic observations indicate that implantation of these elastic prostheses may, in some way, predispose the fibrous sheath to develop in a different form. The mesodermal tissue about the Helanca grafts has been observed to pick up elastic stains. Further studies of this phenomenon are under way. Finally, nylon is known to have a somewhat greater affinity for water than such other synthetic fabrics as Orlon, Dacron, and Teflon. Steps have been taken to determine whether other synthetic yarns will lend themselves to the heat-set curling process.

Conclusion

Development of a satisfactory vascular prosthesis is still under investigation. It is now apparent that any number of synthetic fabrics are, at least for short-term use, suitable for the conduction of blood across a vascular defect. Most of these fabrics will develop a smooth internal lining indistinguishable from and functionally identical to endothelium. They all become encased in a fibrous sheath, although the adherence and thickness of this sheath varies considerably. However, close attention to all functional properties of the original part is as necessary here as in any other endoprosthetic investigation. Therefore, suitability of synthetic fabrics for vascular replacement requires judgement by additional criteria. In addition, because clinical application of these prostheses involves delicate and time-consuming surgical technique, it is important that the final product be equally acceptable from this point of view.

Such considerations lead to the surmise that seamless sleeves of elastic synthetic fabric will eventually prove most completely satisfactory. Preliminary observations demonstrate that this material can be made into

readily available prosthetic grafts which lend themselves to acceptable surgical application. Such grafts, having the desirable characteristics common to other synthetic fabrics, provide the additional advantages of distensibility and ease of handling.

It will await further investigation to discover whether proposed refinements of currently available material will make it equally acceptable from the long-range point of view. In the course of these future studies, time will permit greater attention to the important matters of carcinogenicity, durability of fabric, and host tissue reaction to the implantation of other synthetics. Clearer information regarding presence of fixatives, additives, plasticizers, etc., so commonly used in the manufacture of synthetic fabrics, is vital, and necessitates closer cooperation between investigators in this field and appropriate representatives of the plastic industry.

Summary

Observations of the experimental use of 14 synthetic fabrics as vascular grafts in dogs lead to the conclusion that seamless tubes of elastic nylon offer the greatest potential for clinically acceptable vascular prostheses.

Further refinement of currently available elastic seamless sleeves is necessary for their use in human vascular replacement.

Long-term observation of all synthetic grafts remains highly desirable, particularly as regards durability, tissue reactivity, and carcinogenicity.

E. Blumenfeld, R. Jones, M. Berg, D. Worden, A. Beal, F. Beal, and L. Hardy assisted in the completion of these studies, and Drs. Donald M. Glover and Fiorindo Simeone assisted in the preparation of the manuscript.

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DISCUSSION

On Papers by Newton, Weichselbaum, and Butcher and Whittlesey, Sekerak, Blunt, and Hudack

Dr. Charles G. Johnston, Detroit: I am rather impressed by Dr. Newton's dissertation, especially in regard to the studies on distensibility of the vessels and the relationship to volume.

However, I should like to ask Dr. Newton if he feels that the use of equine desensitized grafts is likely to have any place in surgery. I ask this because some years ago I thought we might have to look for a ready supply in animal material for such things. However, more recently we have had no difficulty whatever in supplying good homografts. It is somewhat difficult for me to see how making an animal graft a homograft could be better than the simple method of getting a homograft directly.

We have used the method which was described by Dr. Szilagyi for establishing our arterial bank, and it has done very well. We have had no difficulty with it. It is simple. We always have a ready source of supply of graft material. We always have variations in size sufficient for use, and I can't see quite how a great deal of processing of animal grafts can quite equal this as far as readily available grafts is concerned, nor do I see how it is likely to be quite as useful a process.

Dr. D. Emerick Szilagyi, Detroit: Dr. Whittlesey and Dr. Newton were good enough to ask me to discuss their papers.

I believe that these papers have a great deal of interest. We are far from being in possession of the ideal arterial substitute. Homografts have served well and offer the best prosthetic qualities available at the moment, but as we gather information on their long-term behavior, say two and three years after insertion, their shortcomings are beginning to loom larger. Thus there is need for continued work toward the goal of the ideal arterial substitute.

In the past, two approaches have been followed toward overcoming the disadvantages of homografts. One was the use of grafts of animal origin. The reports on the results with substitutes of this type have been highly variable and even contradictory. It seems very likely that the underlying reason for this variability of behavior may well be the effect of immunological factors working in an unpredictable manner from case to case. Dr. Newton and his associates have produced evidence in favor of this assumption. The de-specification of grafts of animal origin by controlled enzymatic digestion is a logical step in the attempt of eliminating these factors. The question whether their experiments have yielded proof that the antigenicity of the equine grafts has been sufficiently reduced to allow their clinical use can only be answered by longer observation and more extensive trials. My own experiences with long (17-25 cm.) bovine heterografts in dogs have taught me that evaluation of these transplants is most difficult. While about one-third of 20 experimental transplants ruptured within 6 months, about a third stood up very well up to 16 months, only to show extensive degenerative changes at killing.

The other avenue of approach to the ideal substitute has been the employment of plastic prostheses. The ideal prosthesis would be inexpensive, easily available, nonreactive, nonwettable, durable, elastic, and capable of being woven into branching tubes without seams. There is no prosthesis at the present time that fulfills all these requirements. Helanca nylon grafts, which we have tried for the past six months, seem to approach this ideal

as regards elasticity, and I was glad to see that Dr. Whittlesey found these as satisfactory as we have. Unfortunately, nylon is not very durable as a tissue implant and loses much of its tensile strength after one or two years of implantation, and therefore these elastic nylon prostheses will have to be observed considerably longer before their true value can be judged.

I have brought with me three slides that are very similar to those shown by Dr. Whittlesey. I shall present these as added evidence, from a different source, of the exceptionally fine early results that these elastic nylon implants have given.

[Slide] This is an aortogram showing the disposition of a short graft. As you will notice, there is no dilatation, and the graft functions perfectly well.

[Slide] This is the recovered implant at six months.

[Slide] Here the inner lining is shown, with a perfectly fine pseudointima.

I believe one should encourage the authors and those interested in this subject to keep looking for improvement, and perhaps through concerted effort we shall arrive at the ideal prosthesis.

DR. WILLIAM T. NEWTON, St. Louis: I should like to thank Drs. Johnston and Szilagyi for their comments.

In answer to Dr. Johnston's question, in St. Louis we have not experienced the ease of obtaining arterial homografts that Dr. Johnston has in Detroit. At times we have had a rather long waiting list for femoral artery grafts. However, aside from the desirability of finding a substitute for the arterial homograft, we feel that investigations of this type may have significance in their application to modification of the homograft immune response and in their broader implications in the field of tissue transplantation in general.

As pointed out by Dr. Szilagyi, this study only suggests altered antigenicity. Investigations are under way in our laboratory to study the relative antigenicity of arteries treated by a variety of means and the part played by immune responses in the fate of arterial grafts.

DR. ROBERT H. WHITTLESEY, Cleveland: I should like to thank the discussers, particularly Dr. Szilagyi, for the time put on this problem.

I should like to call attention to the amount of time that is currently going into the investigation of synthetic materials for this purpose. Articles dealing with these studies have appeared in the surgical literature of the United States alone at an average rate of two every month during the past two years. There has been much duplication of effort.

Attention is invited to an editorial by Dr. Oscar Creech which appeared in *Surgery* in November, 1955, in which he pointed out all of this. I, for one, would wholeheartedly endorse his suggestion that the whole subject be submitted to a committee of an appropriate one of the surgical societies. This committee should develop all requirements for satisfactory prostheses of this sort, based on the results and observations of all investigation already done. The committee could then place these requirements before appropriate representatives from the plastics industry, with the hope that in this way much time and money could be saved. The need for more satisfactory vascular prostheses is, I think, obvious to all.

The Mechanism of Intestinal Perforation from Nonpenetrating Abdominal Trauma

THOMAS GEOGHEGAN, M.D.
and
BROCK E. BRUSH, M.D., Detroit

Perforation of the bowel from trauma to the intact abdomen occurs with sufficient frequency that most surgeons personally encounter several cases. The high mortality rate, 61% of all reported cases between 1935 and 1942, as cited by Poer and Woliver,[1] hinges upon delay in operative intervention and closure of the perforation. In our series, when the interval between injury and operation was greater than 12 hours, 4 of 6 patients died; whereas only 2 of 14 died when the interval was less than 12 hours. Certain characteristics of the lesion itself hinder early operation and closure. These characteristics are the size of the lesion, its location, and the apparently insignificant trauma which is sometimes involved.

The perforations are usually small. In our 20 cases, the size ranged from 4 mm. to 2 cm. in the 10 instances in which size was recorded exactly, and the size was described as "small" in 6 others. In reviewing 81 cases from the literature, Bosworth states that 61% were 1.5 cm. or less in diameter.[2] Because of the small size signs of peritonitis may be slow to develop. The perforation is surrounded in many instances with normal bowel and mesentery and is usually not associated with other traumatic lesions. It may be overlooked even when the abdomen is explored.

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From the Division of General Surgery, Henry Ford Hospital, Detroit.

Read at the Thirteenth Annual Meeting of the Central Surgical Association, Rochester, Minn., Feb. 24, 1956.

The perforations are not always located where they are supposed to be. It is commonly mentioned that the segments of bowel fixed in position by a short mesentery are most susceptible to this type of injury. This concept is related to the idea that the lesion is a direct crush injury "in which the external force compresses the bowel against the spine or pelvic bones," as stated by Poer and Woliver.[1] However, the perforation may be anywhere along the course of the bowel, and, as can be seen in Table 1, it is most frequently located in the jejunum or ileum. In our cases the bulk of the

TABLE 1.—*Comparison of Sites of Perforation in Other Series*

Site	Poer and Woliver	Bosworth	Hunt and Bowden	HFH
Stomach	4	?	0	0
Duodenum	2	0	1	1(?)
Jejunum	11	5	2	9
Ileum	13	6	3	10
Colon	2	?	0	0
Associated mesenteric injury	?	1	1	1

TABLE 2.—*Distance of Perforations from Fixed Points of Small Intestine in Nineteen Cases*

	Cases
Jejunum distance from ligament of Treitz	
30 cm. or more	6
Less than 30 cm.	2
Site not specified	1
Ileum distance from ileocecal junction	
30 cm. or more	6
Less than 30 cm.	1
Site not specified	3

TABLE 3.—*Data on Twenty Intestinal Perforations from Nonpenetrating Abdominal Trauma*

No.	Mode of Injury	Location of Lesion	Distance from Ligament of Treitz or Ileocecal Junction	Size of Lesion	Associated Mesenteric Injury
1	Struck by wooden pole	Ileum	30 cm.	Small	None
2	Struck by 150 lb. weight	Jejunum	60 cm.	Small	None
3	Auto collision	Jejunum	?	2 small*	None
4	Auto collision	Ileum	?	?	None
5	Pinned to wall by truck	Jejunum	20 cm.	Small	None
6	Struck by metal bar	Ileum	?	Small	None
7	Auto collision	Jejunum	100 cm.	1.5 cm.	None
8	Struck by metal bar	Jejunum	90 cm.	1.0 cm.	None
9	Fell from truck, struck truss; inguinal hernia	Ileum	?	Small	None
10	Auto collision	Jejunum	4 cm.	4 mm.	None
11	Fell against machine	Ileum	100 cm.	Small	None
12	Motorcycle collision	Jejunum	30 cm.	5 mm.	None
13	Crushed between tractor and wall	Jejunum	130 cm.	?	Mesentery stripped for 1.5 feet
14	Struck by streetcar	Ileum	100 cm.	1 cm.	None
15	Caught between conveyor and motor block	Ileum	80 cm.	?	None
16	Struck by shovel	Jejunum	90 cm.	2 cm.	None
17	Struck by wood from power saw	Ileum	60 cm.	1 cm. and 1.5 cm.	None
18	Struck by metal bar	Duodenum†	(1st portion)	5 mm.	None
19	Fell on pavement	Ileum	60 cm.	1.5 cm.	None
20	Attempt to reduce incarcerated hernia	Ileum	60 cm.	1.5 cm.	None

*Two small perforations 30 cm. apart.
†Patient with peptic ulcer history; probably perforated ulcer with incidental trauma.

lesions were well along into the more mobile portions of the jejunum and ileum. Of 20 cases, 6 of the 9 jejunal perforations were 30 cm. or more from the ligament of Treitz, and 6 of the 10 ileal perforations were 30 cm. or more from the ileocecal junction (Table 2). It would appear that a short mesentery which limits mobility of the bowel does not increase the vulnerability to nonpenetrating traumatic perforation.

Perforation of the intestine can occur without a crushing force sufficient to pulverize the wall of the bowel. In Table 3, Case 20 refers to a 63-year-old man who attempted to reduce an incarcerated right inguinal hernia himself by taxis. While pushing on the hernia, he felt a sudden pain in the midabdomen. Symptoms and signs of peritonitis followed. At operation contaminated fluid was found in the peri-

toneum when the hernia sac was opened through a groin incision. A second incision was made in the abdomen, and a 1.5 cm. perforation was found in the ileum about 60 cm. from the ileocecal junction and about 30 cm. from the loop, which was caught in the hernia sac. The linear rent in the long axis of the bowel was surrounded by normal tissue.

Case 19 in Table 3 is likewise illustrative. Here a man without previous abdominal disease fell forward upon a smooth stretch of pavement while slowly walking toward his home. This concussive blow to the abdomen produced a small perforation surrounded by normal tissue in the distal ileum. Perforations with this characteristic appearance are the result of varying types of trauma. Hunt and Bowden describe a lesion found in a 47-year-old man who was caught between a moving tractor and a wall. "A perforation approximately 5 mm. in diameter on the antemesenteric border of the ileum about 2 in. from the ileocecal valve was found. There was little or no evidence of trauma to the intestine surrounding the perforation, and it was our impression that the bowel had been ruptured from the pressure within its lumen."[3]

These small perforations are quite different from those intestinal ruptures produced by severe crushing and shearing forces. A dramatic example of the latter type is given by Sauerbruch in his description of a patient who fell from a height of three stories, striking his abdomen against a pole. The patient's mesentery was torn from almost the entire length of the small intestine, and the bowel was partially severed.[4] Bosworth records two instances in which the bowel was completely transected by nonpenetrating trauma.[2]

Experimental Crushing and Shearing Injuries of the Bowel and Mesentery

In 10 experiments, 50-lb. weights were dropped from heights of from 3.5 to 4.5 ft. onto the abdomens of intact etherized dogs. (Table 4). At autopsy eight of these animals had free blood in the peritoneal cavity. The source of the bleeding in six was from torn vessels in the small bowel mesentery. In these instances the mesenteric attachment

TABLE 4.—*Crushing and Shearing Injuries Produced by Fall of Fifty-Pound Weight upon Abdominal Wall of Ten Dogs*

No.	Height of fall, (Ft.)	Intestinal Rupture	Mesenteric Injury		Injuries to Other Viscera
			With Vascular Injury	Without Vascular Injury	
1	4.5	0	0	+	0
2	4.5	+	+		0
3	3.0	+	+		0
4	3.0	0	+		0
5	3.0	0	0	0	Left renal pedicle severed
6	3.0	0	0	0	Left renal pedicle severed
7	4.5	0	0	0	0
8	3.5	0	+		0
9	3.5	0	+		0
10	3.5	0	+		0

was sheared off the bowel from varying distances; sometimes sizable segments were devascularized. Two animals bled from torn renal pedicles. One animal had tearing lesions of the mesentery between the vascular arcades in the jejunum and ileum without injury to the vessels themselves. In association with shearing lesions of the mesentery and its vessels, two animals sustained shearing, crushing injuries involving the bowel wall itself. These lesions were entirely different in character from the lesions discussed earlier. They consisted of large gaping wounds with irregular borders and were located at the attachment of the mesentery to the bowel wall. In the example depicted in Figure 1, the bowel was partially transected by one of the ruptures. A feature common to these lesions was extravasation of blood into the mesentery and bowel wall surrounding the ruptures. Similar ecchymotic areas were seen in nonruptured segments of bowel (Fig. 2).

Sauerbruch, in 1903, postulated that a blow to the abdomen, by striking two ends of a bowel segment, could create a closed loop with high intraluminal pressure causing a bursting perforation at a distance from

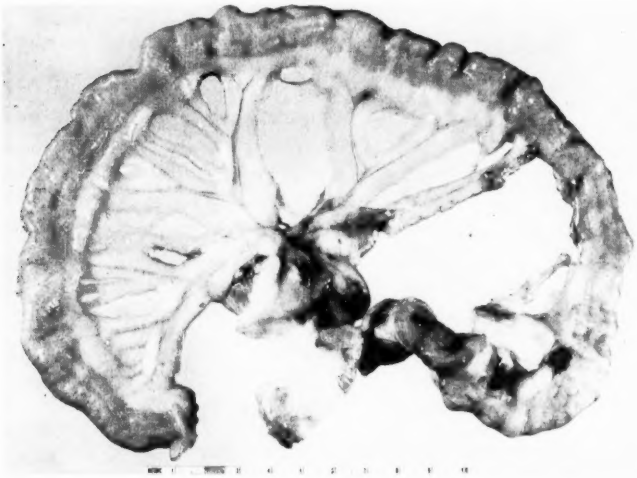

Fig. 1.—Crush wound of the ileum in a dog. The mesentery is sheared off the bowel. The bowel wall is mutilated and almost transected at one point. Intraperitoneal hemorrhage resulted from torn vessels.

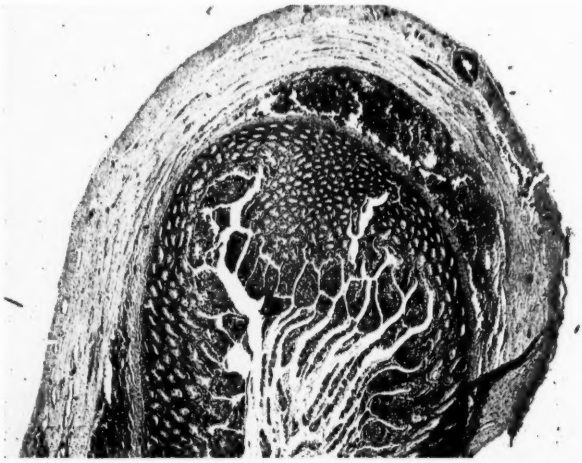

Fig. 2.—Hemorrhage into intestinal wall from crushing wound. Hematoma formation in submucosa. Ileum. Hematoxylin and eosin; reduced about 2/5 from mag. × 44.

the blow.[4] He also discussed two alternate possibilities: a blow which closed off one end of a segment when the other end was blocked by a spasm or kink in the wall, or a blow which raised the pressure in a loop closed by kinks at either end. To equate force applied to an intact abdominal wall with the resultant increase in the pressure within the lumen of the bowel the following experiments were done.

Pressures in the Lumen of the Bowel Produced by Abdominal Wall Trauma

Weights were dropped upon the anterior abdomen of six etherized dogs with hydrostatic balloons placed in various segments of the bowel and peritoneal cavity. The rubber balloons containing about 5 cc. of saline were connected by means of polyethylene tubing brought out through small flank incisons to electronic manometers held in a fixed position beside the animal. In six determinations on each animal, blunt weights of 8 lb. dropped from a vertical distance of 2 ft. produced sudden rises of pressure varying from 150 to 900 mm. of Hg. No clear-cut differences were observed in the pressures recorded in different segments of the small intestine, colon, stomach, or peritoneal cavity. No conclusions could be drawn concerning pressure gradients or susceptible areas from these experiments.

The significant point, as we see it, is that even with relatively small forces the pressure in the lumen of the bowel can approach the bursting strength of the bowel wall (Fig. 3), cited by Wangensteen as a minimum of 300 mm. of Hg for the canine small bowel and 140 mm. of Hg for the human small bowel.[5] Of course, if this were the only factor under consideration, rupture of the bowel would inevitably follow such increases. However, none of the animals in this series sustained bowel rupture. The sudden increase of the bowel pressure is dissipated by kinetic flow as the bowel contents move either proximally or distally under force of the impact. A simple example of this fact is the expulsion of feces from the rectum of an animal receiving such an impact.

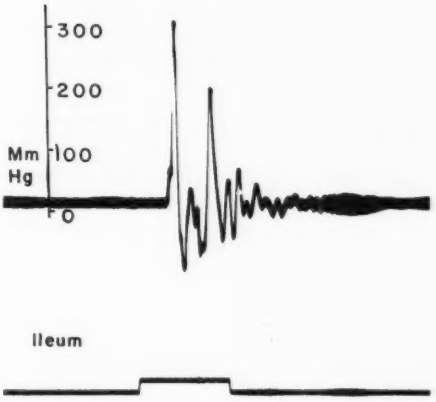

Fig. 3.—Rise in intraluminal pressure of distal ileum of dog with fall of an 8 lb. weight from a height of 2 ft. onto the abdominal wall.

Blows Which Create Closed Intestinal Loops

When the contents of the bowel lumen are prevented from traveling, however, the hydrostatic pressure is directed against the walls of the segment involved. This can occur when the traumatizing force itself suddenly obstructs two ends of a loop of small intestine. In this situation a perforation can occur which is a hydraulic or bursting type of injury dependent on the fluid within the bowel for its production. Figure 4 illustrates such an event. A blunt force was applied to the juxtaposed ends of a loop of canine ileum protected by an excised portion of the abdominal wall. The site of the blow was marked by laceration of the seromuscular coat, but the submucosa remained intact. At about 30 cm. from the site of the blow a 5 mm. perforation occurred on the side of the bowel wall.

Comparison of the Effects of Direct Crushing Forces and Hydraulic Forces on Segments of the Intestine

An experiment was set up in which a flat 50 lb. weight was dropped consecutively onto eight excised empty segments of canine small

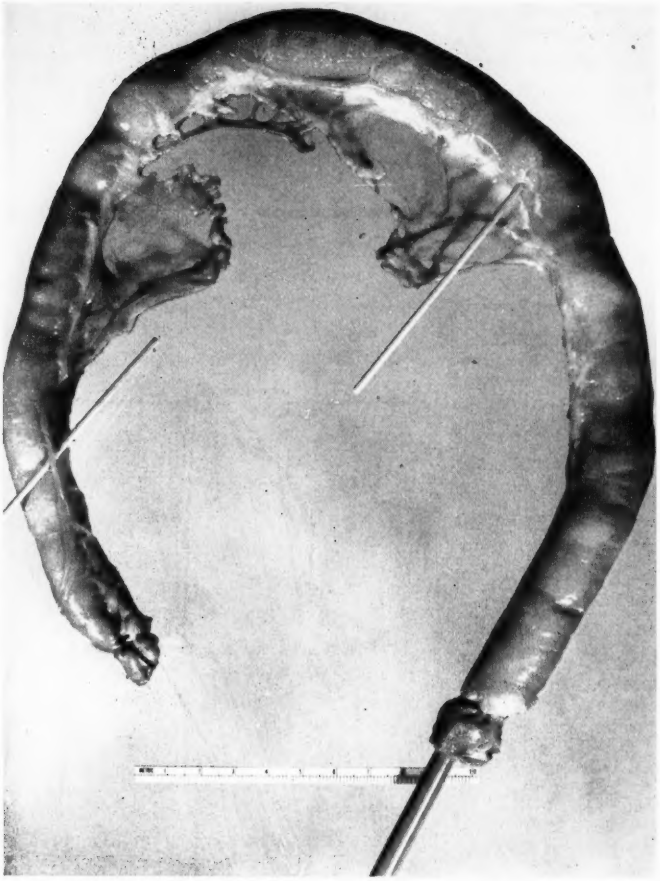

Fig. 4.—Loop of dog's ileum traumatized on its juxtaposed ends. Seromuscular laceration at site of blow marked on left. Perforation at a distance from the blow. Stick inserted into perforation.

intestine protected by the thickness of the abdominal wall from distances of 6 and 12 in. No disruption of the integrity of the intestinal wall occurred. A small seromuscular laceration was seen on one segment of the 12 in. group (Table 5). The experiment was repeated with use of similar segments which had been filled by water from a tap, following which the open ends of the segments were closed. In each of

TABLE 5.—*Fifty-Pound Flat Weight Dropped onto Thirty-Centimeter Segments of Empty Bowel Protected by Abdominal Wall*

6 In. Height		12 In. Height	
Segment	Injury	Segment	Injury
Jejunum	None	Duodenum	Seromuscular rent at site of blow
Jejunum	None	Jejunum	None
Ileum	None	Jejunum	None
Ileum	None	Jejunum	None

TABLE 6.—*Fifty-Pound Flat Weight Dropped onto Thirty-Centimeter Filled Closed Intestinal Segments Protected by Abdominal Wall*

6-In. Height				12-In. Height			
Segment	Site of Perforation on Wall	Distance from Blow	Size of Perforation	Segment	Site of Perforation on Wall	Distance from Blow	Size of Perforation
Ileum	2 o'clock	0	2 cm.	Duodenum	4 o'clock	15 cm.	3 cm.
Ileum	2 o'clock	1 cm.	6 mm.	Jejunum	2 o'clock	3 cm.	2 cm.
Ileum	2 o'clock	0	2 cm.	Jejunum	12 o'clock	15 cm.	2 cm.
Ileum	2 o'clock	10 cm.	8 mm.	Jejunum	5 o'clock	0	5 cm.

these eight experiments small perforations of the bowel wall occurred (Table 6). The perforations were located either near or at a distance from the site of the blow. They were structurally similar. Each consisted of a longitudinal rent in the bowel wall (Fig. 5). The seromuscular opening was longer than the hole through the submucosa. The muscularis splits first in response to pressure within the lumen (Fig. 6). When the holding strength of the submucosa is ex-

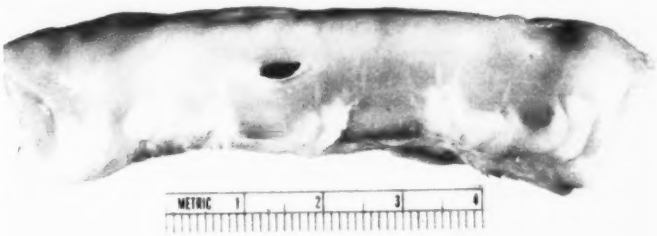

Fig. 5.—Characteristic bursting perforation in ileum of dog, demonstrating the isolated nature of lesion with surrounding normal tissue. The seromuscular rent is larger than the hole through the submucosa. Contrast with Figure 1.

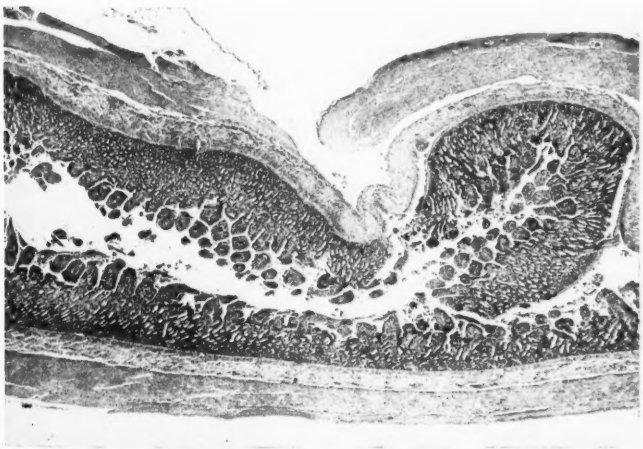

Fig. 6.—Splitting of muscularis and mucosa in response to pressure within the bowel lumen. The submucosa bursts last. Ileum. Hematoxylin and eosin; reduced about 2/5 from mag. × 34.

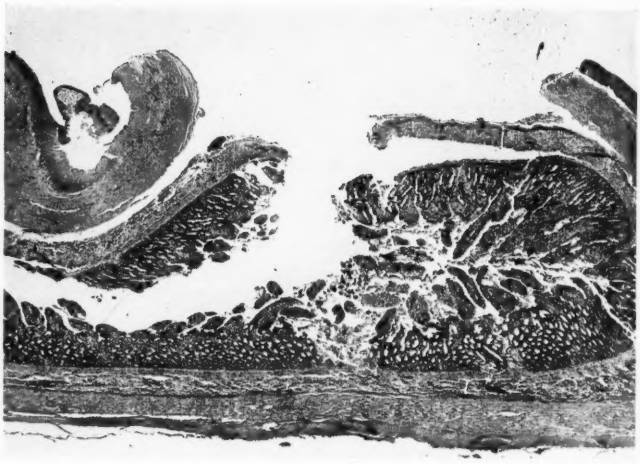

Fig. 7.—When the holding strength of the submucosa is exceeded, a bursting perforation occurs. The opening in the muscularis is larger than that in the submucosa. Ileum. Hematoxylin and eosin; reduced about 2/5 from mag. × 34.

ceeded, the characteristic bursting perforation occurs (Fig. 7).

Vulnerable Area of the Bowel Wall

The tunnel made by the vasa recta through the muscularis and submucosa before breaking up into the submucus plexus represents a vulnerable structural point on the wall of the intestine (Fig. 8). The layers of the muscular coats are separated by the vessel as it courses through them, and the elastic fibers of the submucosa are interrupted (Fig. 9). When the pressure within the lumen is suddenly increased, it is at this point where the intestinal bulkhead is thinnest that the break in continuity of the wall is located.

Comment

In correlating our experimental and clinical data, it appears to us that different types of intestinal rupture may take place as the result of trauma to the intact abdominal wall. Shearing and crushing lesions of the bowel are the product of blows from large and probably acutely angled objects or falls from heights in which the abdomen is traumatized. Tearing and crushing injuries of the bowel wall in our experiments were characterized by irregular gaping ruptures and extravasation of blood into the tissues of the site of the blow. A force which ruptures the bowel wall by direct crushing also disrupts the walls of the vessels supplying the injured segment.

Intestinal perforations from trauma to the intact abdomen in our experience are usually isolated lesions surrounded by normal-appearing tissues. They are found in the mobile portions of the small intestine oftener than in segments fixed in position by a short mesentery and are characterized by linear rents in the seromuscular layers with small openings through the submucosa. Experimentally, lesions with identical features can be produced by hydraulic forces in traumatized closed loops which burst the intestinal wall from within. The quantity of the bowel contents and the placement of the traumatic force would be important considerations in clinical duplication of this mechanism.

The exact explanation for the predilection of traumatic perforations for certain segments of the intestine is not completely clear. The fixation of a segment by a short mesentery does not make it more vulnerable. In fact, the duodenum seems to enjoy a relative immunity from this lesion. The perforations in the jejunum and ileum do not occur at their fixed points as a rule, but at some distance from them. The lack of duodenal involvement could be explained in

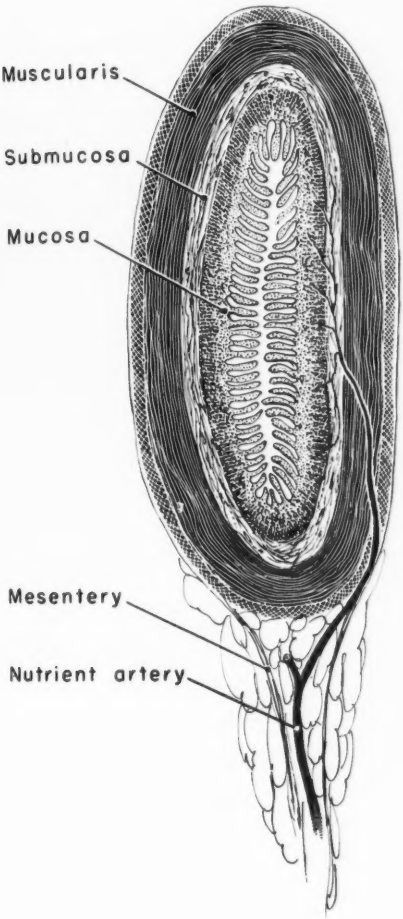

Fig. 8.—The path of the vasa recta through the layers of the intestinal wall provides a potential weak point at which bursting perforations occur. Drawn from section of canine jejunum. Compare with Figure 9.

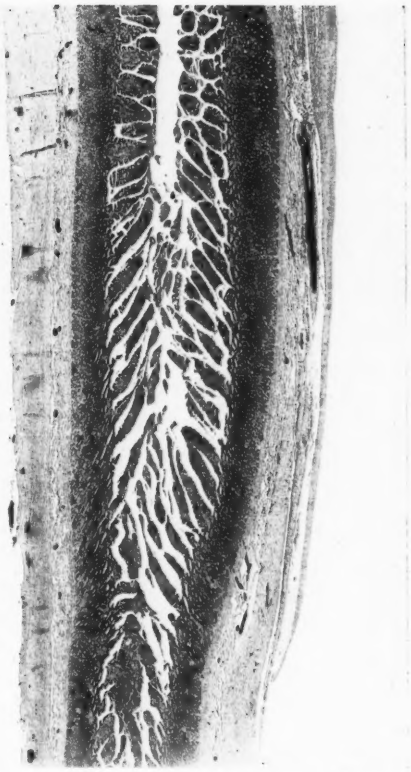

Fig. 9.—Section of canine jejunum. Nutrient artery injected with particulate suspension. Path of artery splits the muscular coats and separates the elastic submucosal fibers. The intestinal bulkhead is weakest at this point. Compare the two sides of the intestinal wall. Hematoxylin and eosin; reduced about ½ from mag. × 34.

two ways. It is hidden behind much of the rest of the small intestine and would thereby receive the direct brunt of abdominal blows less frequently. More important perhaps is the fact that a striking object would be unlikely to occlude both ends of a segment of duodenum so that its wall was acutely distended by the intraluminal pressure. The stomach and large bowel, which are almost never the site of these lesions, are perhaps protected in the same fashion.

An appreciation of the characteristics of differing types of nonpenetrating traumatic perforations should serve as a guide to treatment. No one could miss a lesion such as that depicted in Figure 1. The bleeding from the torn mesenteric vessels and leakage from the mutilated, transected bowel would produce signs demanding early operative intervention and repair. The small perforations, such as in Figure 5, constitute problems of management. They are often the product of insignificant trauma. They seldom produce free air on roentgen examination of the abdomen. They give rise to signs of peritonitis slowly. And they can be overlooked during exploration of the

abdomen unless the small bowel is carefully examined.

Conclusions

Beside the need for early operative intervention in cases of nonpenetrating traumatic intestinal perforation, we wish to stress the importance of searching for small bursting lesions by careful inspection of both sides of the small bowel throughout its length, as well as the more obvious areas of lacerated bowel and torn mesentery.

DISCUSSION

DR. MORRIS T. FRIEDELL, Chicago: In June, 1942, at the Battle of Midway, one of our destroyers pulled alongside a carrier which was sinking. At that time the depth charges of the destroyer were in what was known as the armed state. The carrier sank, with the destroyer. There were many men in the water at that time, who were exposed to immersion or underwater blast.

A number of the survivors were brought to the Naval Hospital at Pearl Harbor with lesions in the gastrointestinal tract which corresponded to the external nonpenetrating damage that has been evidenced in these Slides.

Ordinarily, when a destroyer sinks, the arming mechanism is supposed to be disarmed, and so these injuries were seen only seldom during the war. However, we had some 20 patients with perforation of the gastrointestinal tract, apparently overriding the spine, the mechanism probably being the same as that reported in pulmonary blast injury in which hemorrhage, ecchymosis, and so on, occur in the pulmonary alveoli. (Friedell, M. T., and Ecklund, A. M.: Experimental Immersion Blast Injury: Preliminary Report, *U. S. Navy M. Bull.* 41:353-363 (March) 1943; Friedell, M. T., and Burke, R.: Preliminary Appended Report on Causation of Blast Injury, *U. S. Navy M. Bull.* 41:363-366 (March) 1943.)

DR. ROBERT M. ZOLLINGER, Columbus, Ohio: Prior to 1953, in 915 cases we had 11 patients, or an incidence of about 1 per 100. These statistics were provided for me by Dr. Ullery, of the Department of Gynecology. However, in the 1953-1954 period, 225 cases were treated, and we have had radiation enteritis in 20. During this period the external radiation was increased, along with the routine use of Co^{60}. In other words, most of these patients who were in difficulty had total dosages between 9000 r and 14,000 r, with an average of about 12,000 r.

Concerning treatment we agree very much with the authors. You must be conservative as long as you can. We have resorted to the use of long tubes for a period of time to control the signs and symptoms of obstruction. We have carried out colostomy and resection in some cases. Since the healing is not good, the blood volume must be replaced. Factors of sepsis are always a problem. We believe that the use of very heavy external radiation must be curtailed.

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Gastric Mucosal Capillaries in the Human

E. B. MILLER, M.D.
and
V. A. HASZCZYC, M.D., Detroit

A blood shunt explaining intermittency of function of the stomach, to our knowledge, was first suggested by Barlow, Bentley, and Walder in 1951.[1] These men demonstrated the shunt functionally by perfusion experiments and by radiophotomicroscopy. These findings are in accord with Zweifach's basic concept of the functional capillary unit,[2] which is arranged so as to bypass tissue at rest, except for maintenance blood supply, and so as to flood the capillaries when work is demanded of the tissue in question. Zweifach reported his concept in 1939. It is illustrated in Figure 1.

In 1954,[3] we reported a comparison of the number of blood-filled capillaries per square millimeter between ulcerative and nonulcerative disease of the stomach. These counts were made by calibrating a standard monocular microscope field against a blood-counting chamber. There was demonstrated from the slides of the University of Michigan in Ann Arbor, Department of Pathology, a significantly greater average number of blood-filled capillaries in the mucosa of those stomachs having ulcerative disease.

The above led us to be alert for some opportunity to observe the gastric mucosa in vivo. The following summary reports such a case.

Submitted for publication April 3, 1956.

Read at the Thirteenth Annual Meeting of the Central Surgical Association, Rochester, Minn., Feb. 24, 1956.

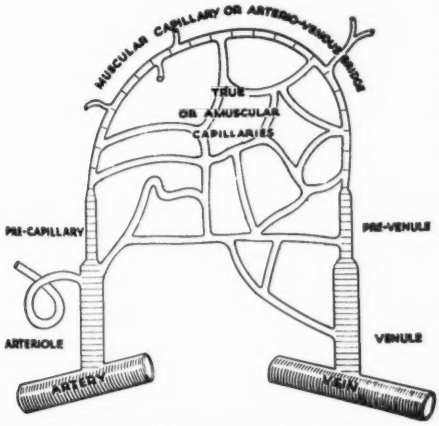

Fig. 1.—Zweifach's concept of the basic capillary functional unit. (Reproduced from article by E. B. Miller: A Study of the Capillaries of the Gastric Mucosa, *Surgery* 36:898, 1954, published by The C. V. Mosby Company, St. Louis.)

Report of a Case

A 59-year-old man had a disarticulation of the right lower extremity at the hip joint on June 16, 1953, for a fibrosarcoma of the upper third of the right thigh. Following the operation he did well and had no trouble until readmitted to the hospital in July, 1954, with complete esophageal obstruction. This was due to bilateral pulmonary metastases causing extrinsic pressure on the esophagus. The patient was examined by esophagoscopy, and nothing could be passed beyond the point of obstruction. He was informed as to the nature of a permanent gastrostomy, following which he expressed the desire that one be done. On July 15, 1954, it was done, as illustrated in Figures 2 through 5. Following the permanent gastrostomy and feeding by the same means, his general condition improved temporarily. He died on Oct. 12, 1954.

Through this gastrostomy it was possible to view the entire stomach and to look into the lower esophagus and into the duodenum, using a sigmoidoscope. It offered the opportunity of repeated biopsy of the gastric mucosa under various conditions. The following tests were done:

On Aug. 24, 1954, the patient was observed at 9:55 a.m. He had finished eating at 8 a.m., and at the time of observation he was comfortable. The stomach was quiet and empty. The interior of the stomach was viewed with the sigmoidoscope, and a biopsy of gastric mucosa was taken, which had an average blood-filled capillary count of 31 per square millimeter. At 9:56 a.m. he was given 1 mg. of histamine by hypodermic injection. By

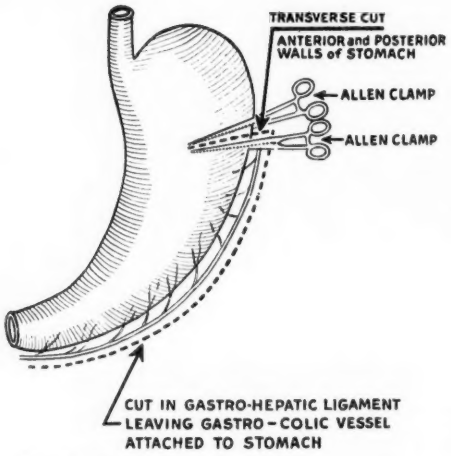
TRANSVERSE CUT
ANTERIOR and POSTERIOR WALLS of STOMACH
ALLEN CLAMP
ALLEN CLAMP
CUT IN GASTRO-HEPATIC LIGAMENT LEAVING GASTRO-COLIC VESSEL ATTACHED TO STOMACH

Fig. 2.—First step, permanent gastrostomy.

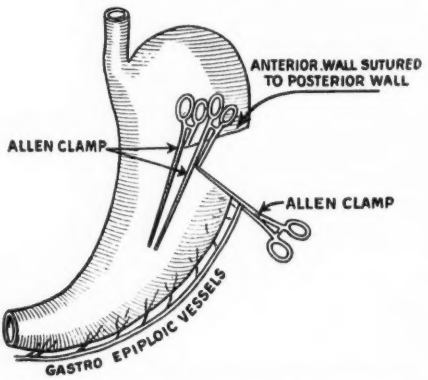

Fig. 3.—Second step, permanent gastrostomy.

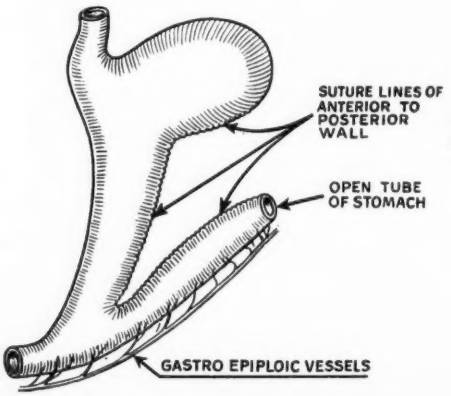

Fig. 4.—Third step, permanent gastrostomy.

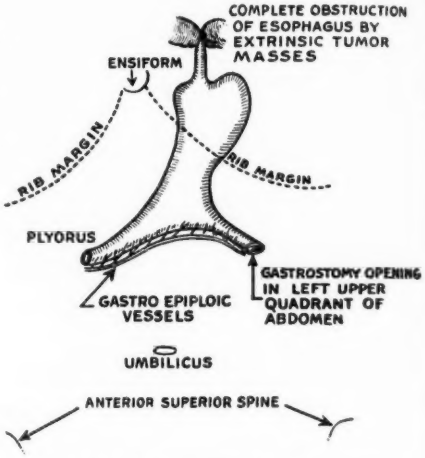

Fig. 5.—Final appearance of gastrostomy.

10:10 a.m. his face was slightly flushed. There was no particular subjective change. At 10:12 a.m. the gastric mucosa had an average blood-filled capillary count of 53 per square millimeter. This was 16 minutes after the injection of histamine. By 10:30 a.m. the gastric mucosa was secreting a clear fluid, which promptly turned blue litmus red. A capillary count at 10:46 a.m. was 51 blood-filled capillaries per square millimeter. By 11:45 a.m. secretion was less and a count was 45 capillaries per square millimeter. This series of observations is illustrated in Figure 6.

On Aug. 29, 1954, the patient was observed at 10:10 a.m., approximately two and one-half hours after having eaten. He was comfortable. His pulse rate at that time was 112 per minute. A biopsy specimen in this fasting state was taken at

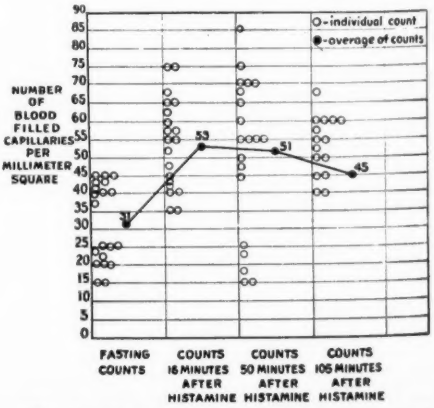

Fig. 6.—Biopsies from human stomach through permanent gastrostomy before and after histamine.

10:25 a.m., on which the blood-filled capillary count was 39 per square millimeter. At 10:30 a.m. he was given, by hypodermic injection, 1 cc. of 1:1000 epinephrine (Adrenalin) solution. At 10:43 a.m. his pulse rate was 128 per minute. He felt slightly short of breath, and there was a pallor of his face. At 10:47 a.m. a biopsy specimen was taken, on which the blood-filled capillary count was 34 per square millimeter. At 10:53 a.m. the patient felt slightly nauseated and weak, and his pulse rate was 142 per minute. He was breathing quite rapidly and stated that he felt very nervous. At 11:05 a.m. the patient felt better and the pallor of the face was less. His pulse rate was 138 per minute. At 11:15 a.m. additional biopsy specimens were taken, upon which the blood-filled capillary count was 27 per square millimeter. This was approximately 45 minutes after the injection of epinephrine. A biopsy was done at 11:59 a.m., on which the capillary count was 30 per square millimeter. This series of observations is illustrated in Figure 7.

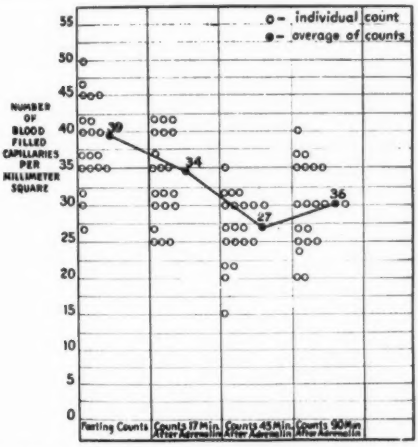

Fig. 7.—Biopsies from human stomach through permanent gastrostomy before and after epinephrine (Adrenalin).

On Sept. 4, 1954, at 10:10 a.m., the patient was observed in a fasting state. He was comfortable, having last been fed at 7 a.m. His pulse rate was 112. A fasting-state biopsy specimen taken at 11:25 a.m. had a blood-filled capillary count of 32 per square millimeter. At 11:30 a.m. a dose of 0.0012 gm. of atropine sulfate was given by hypodermic needle. At 11:40 a.m. there was no subjective change. At 11:48 a.m., 18 minutes after the atropine injection, a biopsy specimen had a blood-filled capillary count of 23 per square millimeter. By 11:50 a.m. the patient noticed dryness of his mouth, and it was noticed by the observer that his face was flushed. At 12:20 p.m. a capillary count was 31 per square millimeter; this was 50 minutes after the injection of atropine. A final count was taken at 1 p.m.; this was 26 blood-filled capillaries per square millimeter. This group of observations is illustrated in Figure 8.

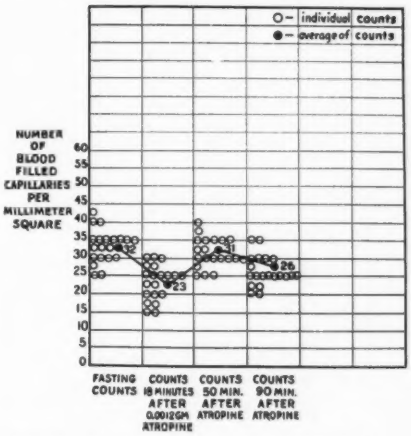

Fig. 8.—Counts before and after atropine.

Beginning on Sept. 14, 1954, the patient was given 25 mg. of adrenocorticotropic hormone four times daily intramuscularly. This was continued for six days, following which a series of fasting biopsies were done which are compared with previous fasting in Figure 9.

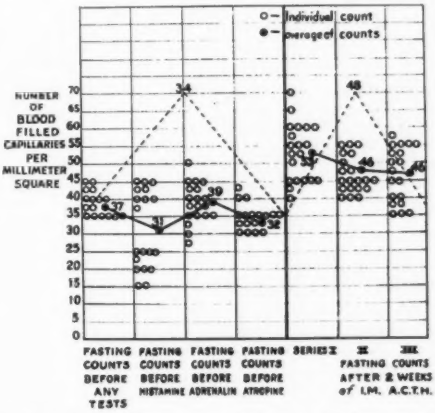

Fig. 9.—Fasting counts before and after corticotropin (ACTH).

In conclusion, it is believed by us that the above observations on a permanent gastrostomy give support to the existence of a functional blood shunt in the stomach. It is believed that there is enough variation in

the number of blood-filled capillaries to indicate that when the stomach is at rest or under the influence of atropine or epinephrine there are fewer blood-filled capillaries than when the stomach is secreting or subject to vagus activity or histamine or to adrenocorticotropic hormone. We support the report of Barlow, Bentley, and Walder and agree with their interpretation of the manner in which a blood shunt functions in the stomach.

Summary

A case has been presented requiring a permanent gastrostomy. Through the gastrostomy repeated biopsy specimens were taken after injection of histamine, epinephrine, atropine, and adrenocorticotropic hormone. There are more blood-filled capillaries per square millimeter in the gastric mucosa following injection of histamine and adrenocorticotropic hormone than there are in a fasting state, or following the administration of epinephrine or atropine.

DISCUSSION

DR. M. F. A. WOODRUFF, Dunedin, N. Z.: I do not feel competent to discuss the main part of this extremely interesting paper, but I should like to make two very brief remarks about gastrostomy.

I think that we shall all agree that the indications for this operation are extremely meager. Some four years ago I happened to have referred to me two extremely emaciated infants, ages 2 and 3 years, respectively, with virtually complete esophageal obstruction due to reflux esophagitis. In both of them a gastrostomy was performed, and they were still alive when, leaving New Zealand, I lost track of the children later.

The point I should like to make is that this was a useful operation. The children were maintained in excellent health. Their gain in weight was normal. Indeed, their strictures relaxed remarkably. The first point is that gastrostomy, I think, is sometimes useful.

The second point is that if you make the gastrostomy, I am convinced that you should do as was done in the case illustrated here and make a definite mucosa-lined tube. I turn down a flap hinged on the greater curvature of the stomach. Then you can use a method described by Edgar Kaye in Australia before the war, that of feeding a perfectly normal diet, whatever the person's family is eating, not homogenized food but minced, not as fine as the usual slush which is given, and put in with a certain amount of pressure. A very convenient instrument for that purpose is the old-fashioned "grease gun."

This is an operation which is seldom indicated but which should not be entirely forgotten.

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Subtotal Gastrectomy for Peptic Ulcer

A Comprehensive Review of Two Hundred Thirty-Six Cases with Emphasis on the Treatment of the Ulcer Which Causes Obstruction

WILLIAM S. CAUDELL, M.D.
C. MARSHALL LEE Jr., M.D.
and
CARL A. LIEBIG, M.D., Cincinnati

Dissatisfaction with the results obtained by conservative methods has led, during the past 20 years, to a more aggressive approach to the treatment of peptic ulcer and to the use of gastric resection in an increasing proportion of cases. Yet if the results of resection were indeed as favorable as many reports would suggest, there would be little need for the numerous published appraisals of one technique as compared with another or for the continual restless search for better methods. A good deal has been written about the management of the patient whose ulcer is bleeding severely or has perforated. Extensive consideration has been given to the anatomical or physiological merits of the Billroth I and Billroth II principles, and to departures from either of these basic techniques in the elective surgery of peptic ulcer. In most of the studies in the latter group emphasis has been on the operation itself rather than on the condition of the patient to whom it is applied. It has become increasingly clear that generalizations are not uniformly applicable to the individual case and that, in the last analysis, the net result is dependent on the infinitely variable combinations of conditions presenting in each patient, on the experience and versatility of the surgeon, and on his judgment in employing an operation best suited to the case in hand. We believe that periodic evaluation of results should be directed toward better understanding of the principles on which such judgments are based, with emphasis on adapting the operation to the patient's needs rather than on his response to a preselected procedure.

With this objective we have undertaken a critical analysis of the records of 236 patients subjected to subtotal gastrectomy for peptic ulcer during the five-year period from June, 1949, to June, 1954.

As a basis for further analysis, these 236 cases have been classified according to location of the ulcer (gastric 48; duodenal 183; marginal 5) and according to the reason for operation, with a correlation of the average age and average duration of ulcer symptoms of the patients in each category. The results of this arrangement are recorded in Table 1 and confirm the usual observation that serious bleeding is commoner in older patients. On the other hand, the belief that obstruction tends to occur oftenest in elderly persons with "burned-out" ulcers is not supported by these data, since the average age of the patients in this group was 46 years. The duration of symptoms was eight or more years in patients whose precipitating factor was pain (whether of gastric or duodenal origin), noncritical bleeding, or obstruction, and in the last category duodenal ulcer was a common offender. Most of the patients with long histories of ulcer symptoms were so impressed with the relief afforded by operation that they expressed, spontaneously, the wish that it could have been provided for them sooner. It is also note-

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From the Department of Surgery, University of Cincinnati College of Medicine, and the Surgical Services, Cincinnati General and Veterans Administration Hospitals, Dayton and Cincinnati.

TABLE 1.—*Analysis of Clinical History of 236 Patients Subjected to Subtotal Gastrectomy for Peptic Ulcer, Five-Year Period from June 1949, to June, 1954*

	No. of Cases	Average Age of Patients	Average Duration of Symptoms of Ulcer, Years
Duodenum			
Pain	91	40	8
Bleeding			
Emergency	13	54	2.4
Elective	36	42	9
Obstruction	43	46	10
Stomach			
Pain	9	49	8
Bleeding			
Emergency	9	61	2.5
Elective	1	72	4
Obstruction	6	51	5
Possible Ca	23	51	4
Marginal ulcer	5	57	18

worthy that patients requiring emergency operation for massive bleeding had relatively short ulcer histories, averaging two and a half years or less.

The usual critical technique is to classify patients according to their presenting or predominant symptom and to correlate this with the operative result. In our experience such a simplified approach has seemed inadequate, because relatively few patients meet the basic requirements for this kind of analysis, namely, a single dominant manifestation of their disease. It is true that massive bleeding may so overshadow all other aspects of the patient's complaints that such cases should be considered in a special category. But restricted consideration of patients in whom pain, for example, is the dominant symptom may be misleading. Only 35 (38%) of 91 patients whose pre-

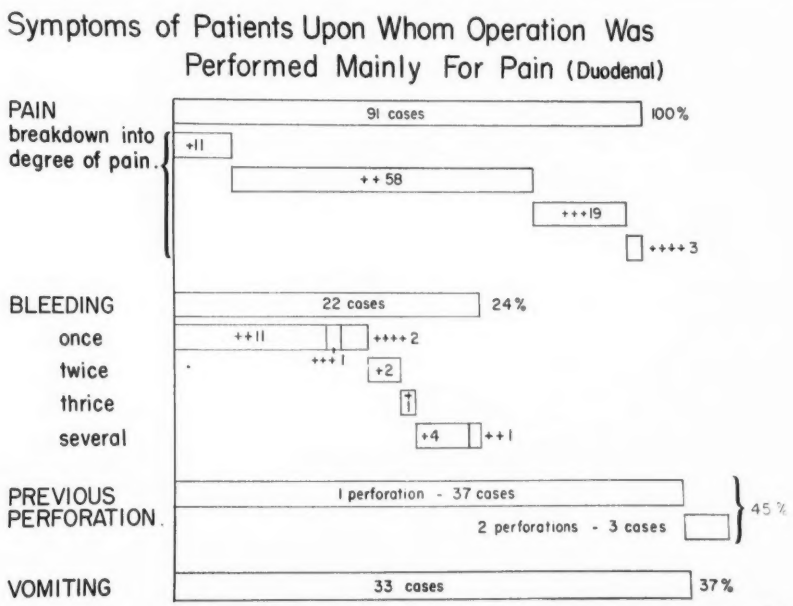

Fig. 1.—The degree of pain was graded from 1+ (mild epigastric distress relieved by antiacids) to 4+ (severe pain not relieved by antiacids or antispasmodics). Bleeding was graded from 1+ (tarry stools without fainting) to 4+ (massive hemorrhage with shock requiring numerous transfusions).

senting symptom was pain were found to have no other symptom. An almost equal number (37%) had both pain and a previous history of perforation; 18% had both pain and a history of bleeding, and 7% had histories of both bleeding and perforation, in addition to their presenting complaint of pain. This analysis is graphically illustrated in Figure 1. Among this same group of patients with essentially painful duodenal ulcer, bleeding had occurred in 24% and perforation in 45% of the cases. The incidence of bleeding was lower in patients presenting with obstruction. It occurred in only 21% of the cases with obstruction of the duodenum, 17% of the cases with obstruction caused by gastric ulcer, and 13% of the patients whose preoperative diagnosis was "possible carcinoma." Although a history of perforation was common (45%) in the group with painful duodenal ulcer, it was infrequent in the cases with the predominant symptom of obstruction (16%) or of bleeding (10%) from the duodenum. As was expected, a history of perforation of a gastric ulcer was even less common, for it was elicited in only 6% of the 48 cases.

The general principle has long been recognized that anterior wall ulcers of the duodenum are more likely to perforate, while those on the posterior wall are prone to erode a major vessel and bleed. If neither of these acute complications occurs, then ulcers in either location, and especially those posterior ones which erode into the pancreas, go on to produce progressive chronic obstruction. The mechanism of such obstruction varies considerably and may include both extrinsic and intrinsic factors. An attempt was made to classify the type of obstruction in each of the 43 cases subjected to elective resection for duodenal obstruction. The results are recorded in Table 2.

It is seen that in the 26 cases (60%) comprising Groups B to E inclusive, the obstructing mechanism was strongly conducive to difficult dissection, and even among the 17 cases in Group A the duodenal dissection was not always easy. There is, therefore, a close correlation between the clinical history (Table 1) and the operative findings (Table 2) in terms of technical difficulty at operation.

TABLE 2.—*Types of Duodenal Obstruction*

Group	Operative Findings	No. of Cases
A	Intrinsic cicatrical stricture only	17
B	Intrinsic stricture combined with constricting adhesions	10
C	Contracture and deformity with penetration into pancreas	8
D	Inflammatory mass with both extrinsic compression and intrinsic stricture	4
E	Massive fibrous scarring, involving liver, pancreas, duodenum and distal stomach	4
	Total	43

In judging the difficulties to be anticipated at operation, we believe that appraisal of the clinical symptoms is of greater value than is the degree of gastric hyperacidity, though the latter may be important to the type of corrective procedure employed. With the exception of emergency cases due to perforation or bleeding, all patients in the series received histamine gastric analyses. Figure 2 is a graphic summary of the results of these studies. In all instances except those gastric ulcers suspected of malignancy, the free hydrochloric acid was abnormally high, suggesting that obstruction is not necessarily consonant with the "burned-out" ulcer of low acidity.

Most of the operations were performed by residents in their fourth, fifth, or sixth year of training, occasionally independently, but usually with the assistance and supervision of a senior surgeon. After removal of an estimated two-thirds to four-fifths of the stomach, the continuity of the gastrointestinal tract was restored by various accepted methods. The gastric remnant was partially closed in most (198) of the cases and the stomach anastomosed either to the jejunum (posterior to the colon in 172 cases, anterior in 3 cases) or to the duodenum (23 cases). In the remaining 38 cases the entire end of the stomach was implanted into the jejunum, posterior to the colon in 35 and anterior to the colon in 3 cases.

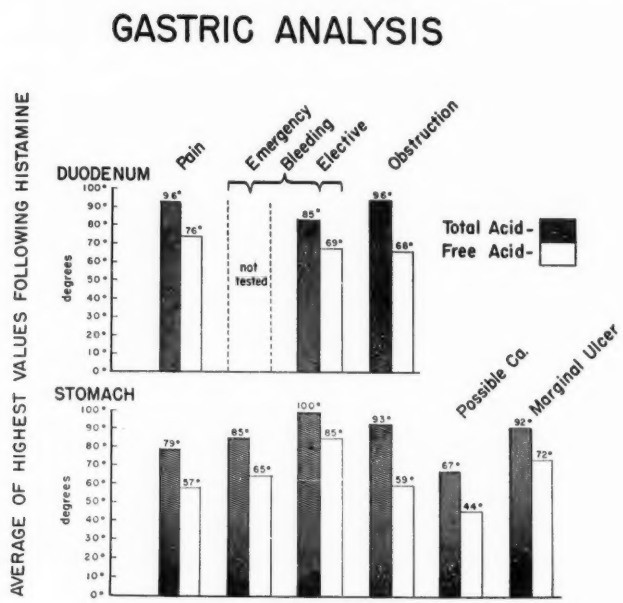

Figure 2

A major objective of this analysis was to determine whether or not it is possible to anticipate technical difficulty prior to laparotomy. As an extension of the data in Table 1, each operative record was assessed on the basis of the following points: (1) difficult dissection of the duodenal stump; (2) unintentional or unavoidable laceration of the duodenal lumen; (3) duration of operation; (4) volume of transfused blood, and (5) serious technical accidents. With respect to the first point, each operation was classified as either "technically difficult" or "not difficult" and the results are summarized in Figure 3. This shows that significant technical problems were encountered in nearly 70% of patients with duodenal obstruction, or about twice as frequently as in any other group. Of the three fatal accidents in the entire series, two occurred in patients with obstruction. In one instance an unrecognized laceration of the common duct was discovered at autopsy, and in another a fatal disruption followed difficult closure of the duodenal stump. The third fatal accident occurred in an elective procedure for bleed-

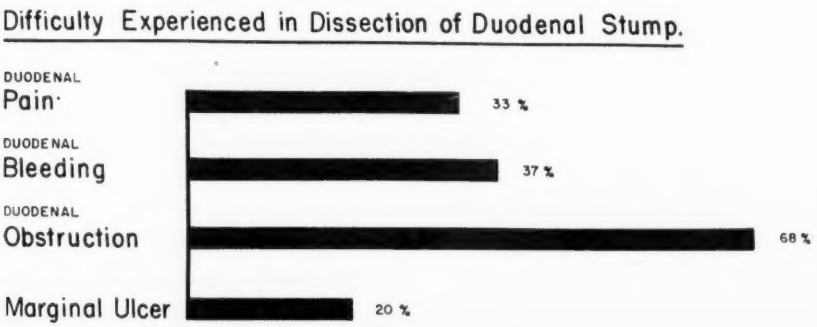

Figure 3

ing. Here the common bile and pancreatic ducts were severed, but the accident was recognized and both were repaired. However, during the lengthy operation a transfusion of 2500 cc. of blood was required, and the patient died postoperatively from atelectasis and hemoglobinuric nephrosis. The temptation to achieve routine removal of all duodenal ulcers, regardless of technical difficulty, was probably responsible for the unfavorable result in these three cases and is mentioned only to be condemned.

The preferred plan of procedure was an initial attempt to free the first portion of the duodenum without opening it, and this was accomplished whenever the dissection was easy. Occasionally, when the dissection was difficult, the duodenum was purposely opened to enable the operator to insert his finger and free it from the surrounding structures, using a technique similar to that employed in freeing a hernia sac. At other times the duodenal lumen was broken into inadvertently. In any event, the duodenal lumen was entered either intentionally or accidentally in 42% of the patients with duodenal obstruction or about four times as often as in the patients with duodenal pain (Fig. 4).

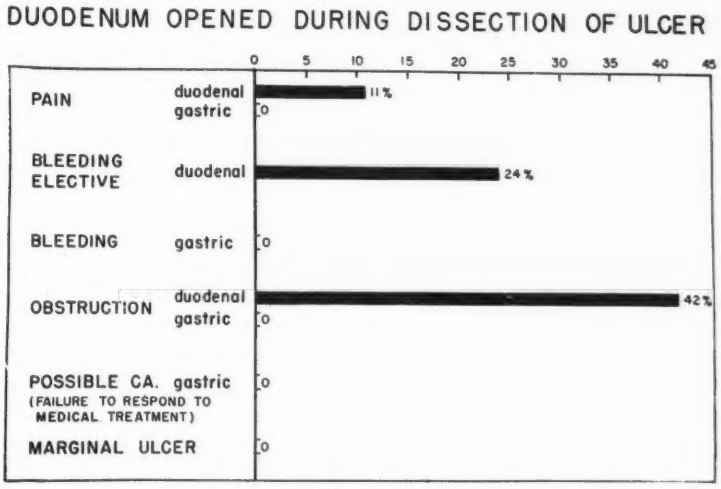

Figure 4

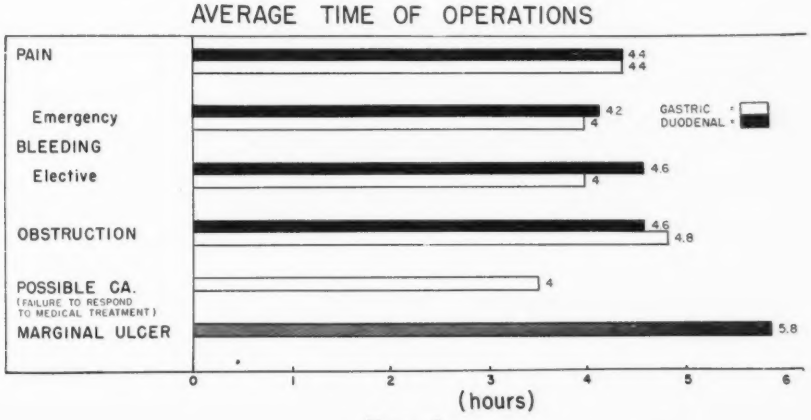

Figure 5

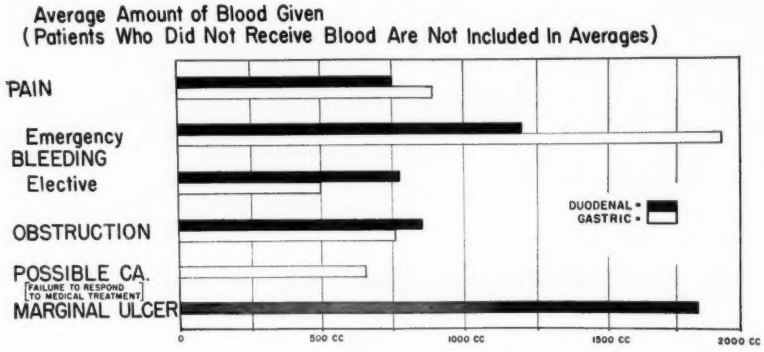

Figure 6

The average duration of operation (Fig. 5) contributed little, if anything, to appraisal of technical difficulty, although it was prolonged slightly in the cases undergoing elective operation for bleeding, or for duodenal obstruction. Similarly, although 86% of the patients received blood during operation, the amounts given showed no correlation with technical problems (Fig. 6). It may be noted that in the last year of this series one of us (W. S. C.) administered a plasma expander (dextran) instead of blood in 29 cases, with no instance of shock either during or after operation. In the last one and one-half years at the Veterans Administration Hospital, Cincinnati, blood has been given only rarely during subtotal gastrectomy.

It appears, then, that the critical analysis tends to support our initial impression that the presence of obstruction, more than any other single factor, should warn the surgeon that a difficult operation may be anticipated and should permit him to consider in advance the available alternatives for dealing with the technical problems that may confront him at the operating table.

Results

1. *Mortality.*—The over-all mortality for the entire series was 5.9% (Fig. 7). The majority of the postoperative deaths (8) occurred in the small group of 23 cases with bleeding peptic ulcers which were operated upon as emergencies, and mortality rate reflects the precarious condition of the patient with massive hemorrhage rather than the technical difficulty of the operation. The bleeding ulcer was in the duodenum in 13 of the 23 cases, in the stomach in 9

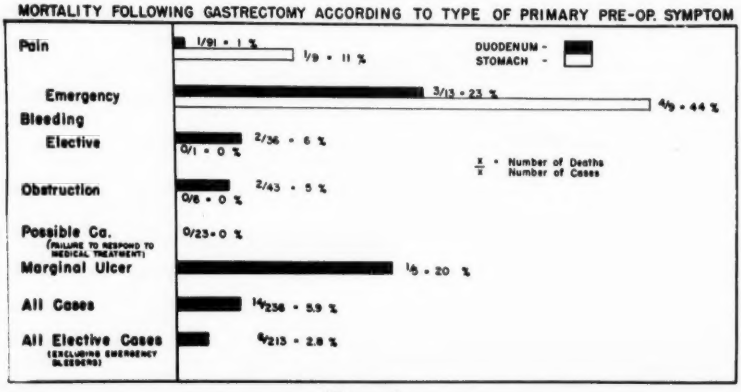

Figure 7

cases, and in the jejunum (marginal) in the remaining fatal case. There were 6 deaths in the group of 213 elective gastrectomies, giving a mortality rate of 2.8% for this series, a creditable record for the numerous residents who operated upon and cared for these patients. Autopsies were performed on 12 of the 14 fatalities, and the primary causes of death are listed in Table 3. The

TABLE 3.—*Cause of Death—Autopsy Findings in Twelve Cases*

Case No.	Primary Cause of Death
1*	Bile peritonitis secondary to tear in common duct
2*	Dehiscence of duodenal stump
3*	Atelectasis and hemoglobinuric nephrosis
4	Peritonitis secondary to dehiscence of gastrojejunostomy
5	Lobular pneumonia and hemoglobinuric nephrosis
6*	Severe enterocolitis and hemoglobinuric nephrosis
7	Severe chronic pyelonephritis and atelectasis, lower lobes
8	Massive dilatation of large and small bowel (cause undetermined)
9*	Encephalomalacia, pons
10	Encephalomalacia, recent
11	Encephalomalacia
12*	Perivascular hemorrhages in medulla oblongata
13	Recurrent massive hemorrhages from upper gastrointestinal tract (no autopsy)
14	Far-advanced pulmonary tuberculosis and pneumonia (no autopsy)

* Elective subtotal gastrectomy.

first three of the six deaths in the cases operated upon electively have already received comment, but the remaining three deaths deserve special consideration. One patient developed high temperature and shock on the fifth postoperative day and received 100 cc. of mismatched blood. Bloody diarrhea and uremia ensued, and he died four days later. The findings at autopsy were severe enterocolitis, pneumonia (lower lobes), hemoglobinuric nephrosis, and diffuse myocardial fibrosis. The diarrhea was so severe that the patient probably would have succumbed to his enterocolitis, regardless of the transfusion accident, and so this death was probably not preventable. The hemoglobinuric nephrosis was, nevertheless, a contributing factor. Another patient developed left-sided hemiparesis six hours after recovery from an uneventful anesthetic and subtotal gastrectomy. A tracheotomy was immediately done because of respiratory difficulty, but he died in progressive coma on the seventh day after operation. Encephalomalacia was found at autopsy. The sixth patient in this group developed high temperature (103 to 105 F) and oliguria and died three days after operation. Autopsy showed only recent perivascular hemorrhages in the medulla oblongata and marked fatty metamorphosis of the liver. It is seen, then, that three of the six deaths after elective resection were from causes not directly related to the technical difficulty of operation and were probably not preventable. The other three deaths were related directly to the management of the duodenal stump.

2. *Postoperative Complications.*—There were 58 patients, including the 14 deaths, or 24% of the series, whose course was complicated following surgery (Fig. 8).

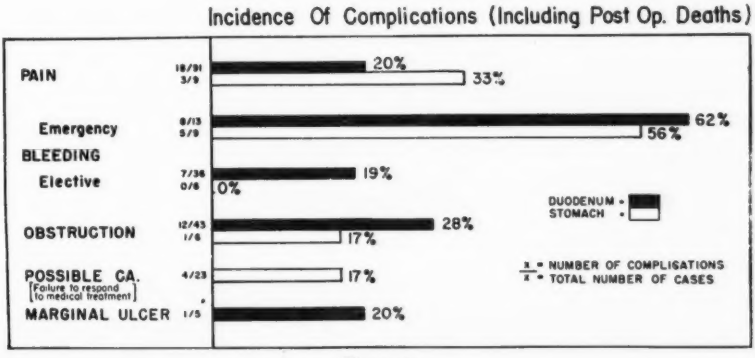

Figure 8

The 14 deaths have been reviewed, and in the remaining 44 patients the 53 complications which occurred are shown in Table 4.

TABLE 4.—*Postoperative Complications (Excluding Deaths)*

Type of Complication	No.
Atelectasis and/or pneumonia	16
Obstruction of anastomosis	9
Wound infection (superficial)	7
Hemorrhage (intragastric)	5
Subphrenic abscess	2
Wound dehiscence	2
Pancreatitis	2
Small bowel obstruction (adhesion)	2
Volvulus of small bowel	1
Volvulus of small bowel about necrotic omentum	1
Hemorrhage (intraperitoneal)	1
Fistula from pancreas through working incision	1
Sinus at site of catheter duodenostomy	1
Perforation of jejunal ulcer (1 month postop.)	1
Thrombophlebitis	1
Bleeding from subcutaneous vessel	1

In common with most other reported experience, the most frequent type of complication was pulmonary, occurring 16 times, or in 7% of the survivors. In a number of the records pneumonia or pneumonitis was mentioned, and the diagnosis of atelectasis was omitted. However, because we believe that primary pneumonia is extremely rare and that pulmonary infection in the postoperative period is almost always secondary to retained secretions and atelectasis, pneumonia and atelectasis have been combined in Table 4. The corollary of this is that the incidence of atelectasis and pneumonia is inversely proportional to the efforts made during and after operation to keep the tracheobronchial tree free of secretions.

Postoperative hemorrhage from the upper gastrointestinal tract occurred five times, but reexploration of the stomach was necessary only twice. In both cases the source of the bleeding was in the Hoffmeister closure of the lesser curvature. To prevent this complication, vessels of the gastric remnant may be individually ligated or a lock suture may be placed tautly as the first layer of closure of the lesser curvature.

Volvulus of the small bowel occurred in two cases, and these patients were explored on the 7th and 21st days after gastrectomy. Whether the mesentery of the small bowel was left in a coiled position when the gastrectomy incision was closed or whether the twist occurred during the postoperative period is matter for conjecture only. It is elementary to mention that the position of the small bowel mesentery should be examined before closure of the wound. In one case localized necrosis of the omentum developed when the gastrocolic ligament had been divided between the gastroepiploic vessels and the transverse colon, thereby jeopardizing the blood supply to the omentum. Although it is somewhat more time-consuming, we prefer to incise the gastrocolic ligament close to the stomach and preserve the right gastroepiploic vessels.

Secondary operations to correct postoperative complications were performed in 18 cases and are summarized in Table 5.

TABLE 5.—*Operations Performed in Postoperative Period*

Type of Operation	No.
Gastrotomy and ligation of bleeding vessel	2
Incision and drainage of subphrenic abscess	2
Secondary closure of wound dehiscence	2
Reduction of volvulus (1 wk. postop.)	1
Reduction of volvulus (3 wk. postop.)	1
Enterolysis for obstructing adhesion	1
Lysis of adhesions about stoma of gastrojejunostomy	1
Closure of perforated ulcer of jejunum	1
Drainage of superficial portion of working incision	6
Ligation of bleeding vessel in subcutaneous tissue	1
Total major operations	11
Total minor operations	7

3. *Follow-Up.*—Satisfactory follow-up study was achieved in 80.9% of the 236 cases and included personal examination by at least one of us. In respect to the entire series, with or without follow-up, the results were interpreted as excellent or good in 60%, fair in 8%, and poor in 7% of the cases. The over-all mortality rate was 5.9%, and 19% of the patients could not be followed. It would be presumptuous to assume that all of the patients who were lost to follow-up had either an excellent or good result. However, it was possible to establish that none of these patients consulted other Veterans Administration Hospitals, which offers some basis for assuming that

the majority of them enjoyed a satisfactory result, although these are not included in the 60% mentioned above. Many of the patients whose results were judged as poor or fair were nonetheless satisfied with their surgical results and were glad to exchange their symptoms of active ulcer for postgastrectomy symptoms of varying severity.

Comment

Some aspects of the cases which have been reviewed deserve special emphasis. The long duration (eight years or more) of symptoms in most of the patients was of interest to us. Prolonged disability, repeated hospitalizations, and absence from work due to symptoms of ulcer are difficult of statistical analysis but were common features in most of the histories.

While the medical management of peptic ulcer has our strong endorsement in suitable cases, this study has given us the distinct impression that "conservative" methods were often unduly prolonged, to the serious disadvantage of the patient. Effective medical management requires complete patient cooperation and close, regular supervision by the physician, an ideal which was rarely achieved in the patients comprising this series of cases. When medical management falls short of the ideal, the incidence of failure is necessarily high. In these circumstances "intractability" must be accepted sooner, and medical treatment should be abandoned.

It is not our contention that surgical treatment is a panacea which restores most peptic ulcer patients to perfect health and relieves them of the necessity for continued restraint and self-discipline, if the best possible result is to be achieved. It is a common assumption that the patient who fails to receive a satisfactory result from operation is a "surgical failure," while the patient who does not respond to medical management has an "intractable ulcer" and may be turned over to the surgeon as a gesture of despair, no matter how good or bad his medical management may have been. With either medical or surgical management, if the patient follows his instruction the results are better than they are if he throws the entire burden on the physician and makes no contributory effort himself. As a rule, the patient who has been subjected to a well-designed surgical procedure can better tolerate neglect of necessary restrictions because more radical measures have been employed to reduce his gastric acidity and to obviate such complications as hemorrhage, obstruction, or perforation. Nevertheless, the incidence of stomal ulcer and postgastrectomy symptoms will always be higher among patients who fail to adhere to the self-disciplines prescribed for them.

To retrace this line of reasoning then, it appears that the patients included in the present study might have been referred for surgical treatment earlier than is usually the case, since inadequate medical management seems to have been unusually common and was continued too long. The incidence of technically difficult operations would have been substantially reduced, and many patients might have been spared months or years of suffering and economic incapacitation.

Once surgical intervention has been decided upon, the corrective procedure best suited to the case in hand is preselected, with due consideration to the possible limitations and modifications which may be imposed by technical difficulties. As a result of the appraisal here reported, certain general principles have been evolved in connection with the surgical management of peptic ulcer, but the discussion will here be confined to the technically difficult aspects of gastric resection, without diversionary consideration of perforation, bleeding, nutritional state, or existing hyperacidity as special problems.

The fact that a patient has been scheduled for a subtotal gastrectomy does not necessarily mean that a portion of his stomach must be removed. There is a tendency among some surgeons to consider a scheduled gastric resection as a sort of personal challenge to be completed at any cost, and

this probably contributes more than any other single factor to the complications of elective gastric surgery. Although methods of dissecting and closing the duodenal stump are as numerous as the techniques for reanastomosis of the gastrointestinal tract, no single procedure has proved satisfactory in all cases. The following technical pattern, assembled from published reports and from our own observations, has been evolved over the past five or six years and has been satisfactory in our hands.

A duodenal ulcer, generally speaking, should be removed when its removal may be accomplished easily and safely. In the presence of exsanguinating hemorrhage its removal is desirable, but not mandatory. The bleeding vessel may be transfixed from within the duodenum with a nonabsorbable suture and the ulcer excluded. Following exclusion, if the entire antrum and pylorus are removed, the ulcer will heal gradually and no further bleeding may be expected. When a duodenal ulcer is densely adherent to the pancreas and no obstruction exists, exclusion may be a safe and effective procedure. On the other hand, when a duodenal ulcer is densely adherent to the pancreas and partial or complete obstruction is present, gastroenterostomy and vagotomy may be preferable. In such a situation, the risk of injury to the common bile or pancreatic ducts is great if the ulcer is removed, and dehiscence of the duodenal stump may be expected if the ulcer is excluded in the presence of more distal obstruction. If initial palpation reveals a large inflammatory mass about the proximal duodenum, a gastroenterostomy and vagotomy should be performed. If no mass is felt, further steps preliminary to resection may be taken without irrevocable commitment until it is established that it may safely be accomplished. The gastrocolic ligament is divided between the gastroepiploic vessels and the stomach, freeing the inferior and posterior gastrocolic ligament and posterior antrum. Next, the remaining right side of the greater curvature may be freed to the pylorus. At this point, the proximal duodenum should be examined. It may occasionally be necessary to incise the peritoneum to the right of the duodenum and to rotate the duodenum and head of the pancreas medially (Kocher's maneuver). This facilitates more detailed inspection and limited dissection, still without commitment to mandatory resection. If the proximal duodenum is densely adherent to the pancreas, or if an inflammatory mass is found about this area, further consideration of gastrectomy may be abandoned and a gastrojejunostomy and vagotomy can be performed. If the above findings are not present, dissection of the duodenal area may be continued and either removal or exclusion of the ulcer may safely be accomplished. Finally, if the dissection has proceeded to the point where resection must be done, before discovery of a quantitatively or qualitatively inadequate duodenum for closure or anastomosis, a catheter duodenostomy may be lifesaving.

There can be no absolute indications for any of these variations in the conduct of difficult operations for peptic ulcer. Much depends upon the technical experience and judgment of the surgeon, and procedures which are safe in one pair of hands may be dangerous in another. Nevertheless, he is the best surgeon who recognizes his own limitations as well as those imposed by the patient confronting him. He will employ the procedure which is most likely to accomplish the desired result with maximum safety.

Summary and Conclusions

A comprehensive analysis is presented of 236 consecutive subtotal gastric resections for peptic ulcer. Particular emphasis is placed on correlation of technical difficulties with the presenting clinical findings. It is noted that technical difficulty was encountered more frequently (68%) and the duodenum was either intentionally or accidentally opened (42%) in cases where obstruction was the dominant feature of the clinical picture. This suggests that the presence of significant obstruction in peptic

ulcer should forewarn the surgeon of a difficult operative procedure and permit him to prepare for it.

The study suggests that inadequate or unsatisfactory medical management is often unduly prolonged. If these failures were recognized earlier and accepted as such, with a prompt decision in favor of surgical intervention, the incidence of technically difficult, high-risk cases could be substantially reduced.

Especial attention is given to the importance of adapting the surgical procedure to the needs of the individual patient rather than evaluation of the technique itself in terms of patient response. Certain suggestions are offered toward increasing the safety of operations performed in the presence of technical difficulties imposed by the character of the presenting lesion.

4759 Harlem Rd., Buffalo 26 (Dr. Caudell).

DISCUSSION

Dr. Claud C. Burton, Dayton, Ohio: I should like to congratulate Dr. Caudell on his excellent presentation. Any obstructive cicatrizing lesion of the duodenum ordinarily is a warning that one should anticipate technical difficulties. In the three lethal cases reported in this series, two fell in this category.

We do not hesitate to transect the duodenum, insert the finger, and free the duodenum, much like freeing a hernia sac. In this way, ordinarily one can prevent any injury to the pancreatic or biliary duct. However, it does not avoid trauma to the pancreas.

I should like to mention one complication of gastrectomy which was not emphasized in the paper and which has given us much concern. It is acute lethal pancreatitis.

In a consecutive series of 348 gastric resections which were done at the Veterans Hospital, Dayton, Ohio, 25% of our deaths were from acute pancreatitis; 60% of these cases had gastrointestinal hemorrhage. At autopsy the pathologist was unable to demonstrate the source of the bleeding.

Of course, this has been reported by other observers. Therefore, from this study it would seem that there are valid indications for revising our criteria for resectional surgery.

I am in full accord with the concept of placing greater emphasis on the fundamental clinical principles which were so well elucidated in this paper.

Dr. Louis T. Palumbo, Des Moines: I want to compliment Dr. Caudell and his associates for an excellent analysis of some of the very important considerations in this type of surgery. I should like to relate our experiences with 231 partial gastrectomies performed for duodenal ulcer and marginal ulcer. This survey was completed about a year and a half ago, and in many respects their results and ours parallel one another.

[Slide] Indications in this group of cases were 51% intractability and 38% pyloric obstruction. Emergency surgery was performed during active hemorrhage in 11%; however, in many of these cases there was a combination of any of these three factors.

You will note that a high percentage of the patients had had previous surgery. In 24%, as shown on the Slide, previous surgery was done for perforated duodenal ulcer, and a smaller number had either a previous gastroenterostomy or a partial gastrectomy.

A high percentage of these patients presented themselves with a history of hemorrhage. Forty per cent of the sixty per cent had either moderate or massive hemorrhage upon admission to the hospital. In this group 99% of the duodenal ulcers or the marginal ulcers were removed, and in only two instances was the ulcer left in situ. I think that that is an important consideration when one speaks about mortality. As we all know, removing and ulcer deep in the head of the pancreas will certainly increase the morbidity and mortality rate.

In this group 60% of the duodenal stumps were opened primarily for dissection purposes; and in our recent 100 cases in the last two years we have opened about 90% to aid dissection and to be sure that we were beyond the fibrotic area of involvement, and also to be sure that we had removed the ulcer.

[Slide] In the nine deaths that occurred in this series, we considered that possibly seven might be due to technical considerations. I am certain that some of these might be decreased by surgeons who are well trained and proficient in this type of surgery.

[Slide] Our over-all mortality in the 231 cases was 3.4%, and in the elective surgery it was 2.7%. In the emergency cases performed because of hemorrhage, the mortality was 7.7%. About 50% of these cases were done by our house officers.

Our preference at the present time is to perform our partial gastrectomy with an anterior gastrojejunostomy in this group of patients.

In the select group of patients who show autonomic nervous instability and a high response to the Hollander insulin test, we combine this type of resection with a bilateral vagus resection.

DR. STANLEY HOERR, Cleveland: I should like to add my compliments to Dr. Caudell and his associates for this study. A study such as this reminds us that gastric resection is an inherently dangerous procedure, and that the duodenal stump is treacherous.

In cases of acute hemorrhage we are probably committed to resection, but I should like to re-emphasize the points that Dr. Caudell brought out, namely, that the ulcer need not be resected but should be excluded. The ulcer base does not contain mucous membrane, and to dig the base out of the pancreas is to invite catastrophe. Furthermore, if one is committed to a difficult resection, it is always wise to open the duodenum prior to closing the stump, and to close the stump with direct visualization.

Dr. Caudell has indicated an even more important policy which undoubtedly is going to save many lives, a decision to perform a lesser procedure than a resection in a difficult case. It takes considerable experience to decide whether a duodenal ulcer is essentially unresectable or not; and if one is working in a center where gastric resection is the only "correct" procedure to do for duodenal ulcer, it takes considerable courage as well to decide not to perform a gastric resection but to perform instead a vagotomy and gastroenterostomy.

I think that we should drop this inelastic attitude and should encourage our residents—and our young surgeons and our old surgeons, too—to perform this much safer procedure of vagotomy and gastroenterostomy either in the poor-risk patient, or after we have sized up the situation, as Dr. Caudell has indicated, when the technical difficulty is going to bring the operative risk out of line.

There is enough experience now with vagotomy and gastroenterostomy so that we know that we can assure our patients of about an 80% good clinical response, and we can tell our patients that there might be 1 chance in 20 that they might have to come back for a secondary gastric resection.

DR. C. MARSHALL LEE JR., Cincinnati: I should like to thank the various discussants. There is very little that I can add to the concepts which Dr. Caudell has expressed. I think that they can best be summarized by a quotation from Napoleon Bonaparte who, in his military maxims, had one maxim which says, "Leave nothing to chance. Always have a plan."

Evidently he took a second look at this for the next maxim says, "Leave something to chance. Always have two plans."

In the surgery of peptic ulcer, with its host of variables in regard to condition and needs of the patient, as well as to the skill, experience, and judgment of the surgeon, even two alternative plans of action may not be enough.

Comparison of Two Methods for Induction of Hypothermia in Dogs

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and
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With the Technical Assistance of Marilyn McG. Helmsworth and Asad Masri

Reduction of body temperature causes physiologic alterations which may enable the surgeon to improve existing techniques for operative procedures. Both Swan and Lewis have demonstrated that surgery under direct vision in the opened heart is possible for certain congenital defects if the patients are first made hypothermic. Other applications of this method can only be speculated upon for the present, however, because of limited information on the fundamentals of the body's response to the condition of reduced temperature. Not only are there gaps in the core of information on this subject, but there are reports of experimental studies which lead to conflicting conclusions. Therefore, a broader application of this method must wait for the completion of more experimental studies. At the present time hypothermia as an adjunctive surgical measure is of established value in a very limited sphere.

Most studies of animals have been made with methods which reduce body temperature by covering the skin with ice or ice water. Both have been used in this laboratory, and hematologic measurements completed as part of these experiments disclosed changes in the cellular elements of the blood.[1] There is the possibility that the changes in the leucocyte and platelet counts and the mean corpuscular hemoglobin concentration are part of the animals' response to reduced body temperature per se. Also, there is the possibility that these changes in blood cellular elements are part of the animals' reaction to a prolonged ice-water bath. It follows, therefore, that the hypothermic state induced by this means may not be a simple one for investigations in reduced body temperature; it may be complicated by the animals' reaction to a barrage of stimuli from the somatic afferent nerves excited by the process of icing.

A group of experiments was completed in which the animals' body temperature was lowered by cooling the blood in an extracorporeal circuit. In these experiments we attempted to eliminate all effects related to washing, shaving, or applying ice to large areas of skin. This report will summarize the results obtained by this method of cooling and compare them with similar measurements in animals cooled by immersion in ice water.

Method

A more complete description of the methods used in this laboratory has been given in earlier publications.* The dogs were an unselected group of average size and were not specially prepared for the experiment. Thiopental (Pentothal) sodium was the principal anesthetic agent, with small supplementary doses of meperidine hydrochloride (Demerol). A mechanical ventilator was used, and determinations of the pH of arterial samples indicated that some degree of acidosis complicated many of the experiments. (This

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* References 1 and 2.

unphysiologic state developed with the same frequency in all three groups of animals.) The trachea was intubated for all experiments, the arterial pressure measured through a cannula in the left carotid, and the venous pressure observed in a manometer attached to the left jugular. A mercury thermometer was inserted into the descending colon.

The apparatus for extracorporeal cooling of the blood consisted of two large steel cannulae and a 36-in. length of Tygon tubing with ¼ in. inner diameter and 1/16 in. wall thickness. The tubing with a cannula on each end was filled with approximately 100 cc. of isotonic saline plus 5 mg. of heparin. One cannula was passed into the left femoral artery, and the other was inserted into the right femoral vein. The pressure gradient from artery to vein made a pumping apparatus unnecessary. A sigma-motor pump was used, however, to control the rate of flow through the tubing. The rate was increased as the animal's temperature fell during the experiment; at the beginning of extracorporeal circulation it was 150 cc. per minute, and as the temperature reduction approached maximum the rate was increased to approximately 400 cc. per minute. Heat was lost from the blood by immersion of from 12 to 24 in. of the Tygon tubing in a pan of acetone and solidified carbon dioxide. The temperature of this mixture varied between —65 C and —75 C. When the shunt was opened at the start, and before the tubing was cooled, the mean arterial pressure did not fall more than 15 mm. Hg. At no time during the experiments was there a rise in the venous pressure.

Results

A control group of five dogs was anesthetized and subjected to the minor surgery necessary for cannulation of the trachea and vessels and then a 90-minute period of partial extracorporeal circulation "without cooling." The average hematologic values at the start of the experiments and

TABLE 1.—*Data on Changes in Five Control Animals Subjected to Anesthesia and Partial Extracorporeal Circulation Without Cooling*

	Avg. Pre-Exp. Values	Avg. Change After 135 Min.
Hematocrit	46.8 vol. %	15.8% increase
Platelet count	550,000 per cu. mm.	9.6% decrease
Leucocyte count	13,960 per cu. mm.	25.1% decrease
Total eosinophile count	286	13.2% decrease
Mean corpuscular Hgb. concentration	32.6%	5.2% decrease

TABLE 2.—*Data on Changes in Eleven Animals Subjected to Cooling by Immersion*

	Avg. Value at Normal Temp.	Avg. Change at 23 C
Hematocrit	46.4 vol. %	27.2% increase
Platelet count	524,700 per cu. mm.	80.7% decrease
Leucocyte count	12,670 per cu. mm.	88.5% decrease
Total eosinophile count	303	85% decrease
Mean corpuscular Hgb. concentration	32.9%	6.1% decrease

TABLE 3.—*Data on Changes in Nine Animals Subjected to Cooling by Extracorporeal Circulation*

	Avg. Value at Normal Temp.	Avg. Change at 28 C
Hematocrit	46.6 vol. %	20.4% increase
Platelet count	547,000 per cu. mm.	24.8% decrease
Leucocyte count	12,910 per cu. mm.	51.2% decrease
Total eosinophile count	284	33.1% decrease
Mean corpuscular Hgb. concentration	32.2%	4.7% decrease

the average percentage changes after 90 minutes of artery-to-vein circulation through the Tygon tubing are given in Table 1.

A second group of 11 dogs was anesthetized and subjected to the same cannulations. Cooling to an average of 23 C was accomplished by immersion in ice water for a period averaging 60 minutes. The starting hematologic values and the average percentage changes are listed in Table 2.

Group 3 included nine dogs cooled by circulation of a small fraction of the cardiac output through cold Tygon tubing. The hematologic values for this group along with the percentage changes associated with this method of cooling are recorded in Table 3.

Comparison of changes in hematocrit in the three experimental groups shows that the trend was toward hemoconcentration in all the animals. This was greatest in those cooled by immersion, the average increase being 27.2%. Factors affecting this change were active even in the control group, however, where the hematocrit was increased by an average of 15.8%.

The process of cooling through extracorporeal heat exchange caused a reduction in platelet count considerably greater than that observed in the control animals. It is possible that many platelets adhere to the wall of the plastic tubing and that part of the thrombocytopenic effect was caused by the apparatus. The group cooled by immersion, however, had a striking fall in platelets: The change was more than three times greater than that observed with extracorporeal cooling.

Animals in the control series with extracorporeal circulation, but without change in body temperature, had an average reduction in leucocytes of 25.1%. Comparison of this change with values obtained in earlier control series suggests that this leucopenic effect is attributable entirely to the plastic surfaces of the extracorporeal circuit.[2] Surface icing caused an 88.5% reduction in leucocyte count, while the fall was 51.2% in animals subjected to blood stream cooling.

Changes of a similar order were found in the total count of eosinophiles. This index of the animal's response showed a marked difference between reactions to blood cooling and reactions to surface cooling. In addition to this, it was noted that use of the shunt without changing body temperature caused a fall in eosinophiles not found in an earlier study of controls without this type of arteriovenous fistula.

There is a significant difference between the mean corpuscular hemoglobin concentration values obtained in animals subjected to immersion and those cooled by circulation of blood through the shunt of plastic tubing. This change in corpuscular hemoglobin concentration may reflect the movement of fluid into the erythrocytes.

One of the fundamental questions in this field of investigation is, "Can a state of uncomplicated hypothermia be produced in the experimental animal?" The ideal experiment would permit study of a cold animal that is free of responses to ancillary conditions. The use of an ice-water bath is the simplest way to reduce the body temperature, but we suspect that in the conditions of these experiments in dogs this method may excite complicated responses. Cold may act as a potent stressor when applied to the skin; therefore, it is possible that a fair portion of the dog's reaction to surface icing is a response to a stress rather than a pattern of reaction to subnormal body temperatures per se.

That hypothermia induced in dogs by surface cooling with ice water is associated with changes in the blood cellular elements was demonstrated in two independent laboratories.† The data in this report were obtained from animals with temperature lowered by blood stream cooling and from others cooled by the usual immersion procedure. The results indicate that dogs' reactions to cooling by the former method differ from the reactions seen in animals cooled via the skin. This suggests, therefore, that changes attributed to reduced body temperature must be evaluated with

† References 1 and 3.

regard to the organ systems through which the heat loss is mediated.

Summary

If changes in blood cellular elements prove to be reliable criteria, the response of dogs to cooling by immersion in ice water is different from their response to blood stream cooling.

Data from three groups of animals indicate that with icing the skin there is greater increase in hematocrit, greater fall in platelet count, leucocyte count, and total eosinophile count, and a greater fall in mean corpuscular hemoglobin concentration than is associated with cooling through an extracorporeal shunt.

The significance of the hematologic changes is uncertain, but the investigation emphasizes that effects that may be attributed to subnormal body temperature may be related more to the method of cooling than to the hypothermic state per se.

The Ellis and Watts Corporation, Cincinnati, and the United States Stoneware Company, Akron, Ohio, gave technical advice and material assistance in this investigation.

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Experimental Repair of Cardiac Septal Defects

Use of Hypothermia with Coronary and Carotid Artery Perfusion

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and
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In the last few years, open cardiac surgery has been employed with increasing frequency for the direct repair of intracardiac defects. Its main use has been in cases of atrial septal defect and pulmonic stenosis. Recently, however, the repair of ventricular septal defects has been carried out experimentally and clinically. Two techniques have been employed for this purpose, the pump oxygenator and hypothermia. We have recently studied several methods which have rendered possible safe open cardiac surgery in the experimental animal with very low incidence of ventricular fibrillation and a high survival rate.* In a series of dogs protected by sinoauricular node blockade with procaine, we have been able to produce and repair ventricular septal defects with survival of all of the animals.[6] We have recently demonstrated that the safe period of vena caval occlusion can be appreciably extended by coronary and carotid artery perfusion with oxygenated blood.[7] The present study concerns the repair of atrial and ventricular septal defects with use of these adjuvants.

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From the Department of Surgery, Indiana University School of Medicine, Indianapolis. Aided by grants from the National Heart Institute, The United States Public Health Service; the Indiana Heart Foundation; the James Whitcomb Riley Memorial Association; and by a contract between the Office of Naval Research, the United States Navy, and Indiana University.

* References 1 through 5.

Material and Methods

Twenty-eight healthy mongrel dogs weighing between 6.5 and 13 kg. were used. Anesthesia was induced by the intravenous administration of from 2 to 4 cc. of a 10% solution of thiopental sodium. Tracheal intubation was carried out, and the dogs were hyperventilated with 100% oxygen by means of an intermittent insufflation apparatus producing between 35 and 45 respirations per minute. Cooling to 30 C was achieved by immersion of the animals in a bath of water and crushed ice. When shivering occurred, it was controlled by the temporary administration of a mixture of ether and oxygen. By the time the chest was entered, the temperature had generally fallen an additional 3 C to 4 C. The blood to be used for the perfusion was withdrawn just before the operation by bleeding hyperoxygenated normal dogs from the femoral artery. The blood was collected in vacuum bottles containing either 20 mg. of heparin or a solution of sodium citrate, citric acid, and dextrose. The blood was stored in a refrigerator kept at 4 C for 20 or 30 minutes.

In all of the animals, procaine blockade of the right atrial-superior vena caval junction was carried out until slowing of the heart rate and changes in the P wave of the electrocardiographic tracing occurred. Blockade was more difficult to carry out in those animals in which the septal defect had been created in a previous operation because of the thick adhesions surrounding the heart and particularly the right atrium and the area of the sulcus terminalis. Following blockade, the venae cavae were occluded with angulated Potts ductus clamps. In all of the animals, the perfusion was delayed for two minutes after occluding the venae cavae, and respiration was continued during this period. The descending aorta and the right subclavian artery were then occluded and the dog put in Trendelenburg's position. The perfusion was started, and the right atrium or the right ventricle was widely opened. The cardiotomy was repaired from 26 to 31 minutes

later with a continuous suture of silk. The blood was perfused at the rate of from 25 to 30 cc. per minute by gravity flow, or, if needed, by manometrically controlled pressure in the infusion flask. All blood lost during the procedure was collected by aspiration and measured carefully. Before the cardiotomy was repaired, sufficient blood was allowed to escape following temporary release of the superior vena cava in order to equalize the amount of blood introduced by perfusion and that removed by aspiration. After repair of the chest wound, the animals were rewarmed to a temperature of 36 C by immersion in a bath of water kept at approximately 45 C. Aspiration of the chest was carried out for the last time, and the animals were left for the following 24 hours in a warm room.

When citrated blood was used and the heart was in standstill, cardiac massage was instituted after caval release, followed one minute later by the intracardiac injection of 4 to 5 cc. of a 20% solution of calcium gluconate. When heparinized blood was given, the heart usually contracted normally for the duration of the experiment and no calcium had to be given, although brief cardiac massage was sometimes necessary. In these dogs, protamine was given intravenously (1.5 mg. for each milligram of heparin) at the end of the operation. Blood transfusions were used in the immediate postoperative period when thought necessary. If fibrillation occurred in either group of animals, the heart was massaged. Unless fibrillation disappeared, three electric shocks of 170 volts and 0.1 second duration were applied. In most cases, before use of electric shock, 1 cc. of 1:10,000 epinephrine was administered into the right heart to increase the myocardial tone and promote a coarser fibrillation.

In all animals, a bilateral anterior thoracotomy in the fourth interspace with sternal transection was used. The perfusion catheter was introduced into the ascending aorta via the left subclavian artery, which was ligated distal to the site of entry of the catheter. The right subclavian artery was occluded at its point of origin with a rubber-shod serrefine clamp, and the descending aorta with a Potts ductus clamp.

Ventricular septal defects had been created in some of the animals between 20 days and 8 months before repair. They were made with a septotome according to a technique previously described by King and associates.[5] At the time of repair, they were all patent. In the others, the defect was created and closed at the same operation. To do so, the exposed ventricular septum was grasped with a toothed forceps and a defect 6 or 8 mm. in diameter was created with a fine scissors. The defect was then dilated by spreading the blades of a Kelly clamp.

Atrial septal defects had been produced in a number of animals from 12 to 120 days prior to the repair.[9] In the others, the defect was made and repaired at the same operation. Large defects were created.

Observations

When heparinized blood was used for the perfusion, the heart maintained a regular rhythm during the entire time of perfusion, and, although the rate tended to decrease, the contractions remained strong and the heart pink. Only in one case did fibrillation develop before caval release. In this particular dog, the blood had clotted in the flask and fibrillation occurred after 16 minutes of caval occlusion when the dog had received only 70 cc. of blood. In addition, through error, the descending aorta had not been occluded in this animal.

In those dogs in which citrated blood was perfused, the heart slowed progressively, until standstill occurred in from three to eight minutes. Fibrillation did not occur before release of the caval clamps.

Repair of Ventricular Septal Defects.—

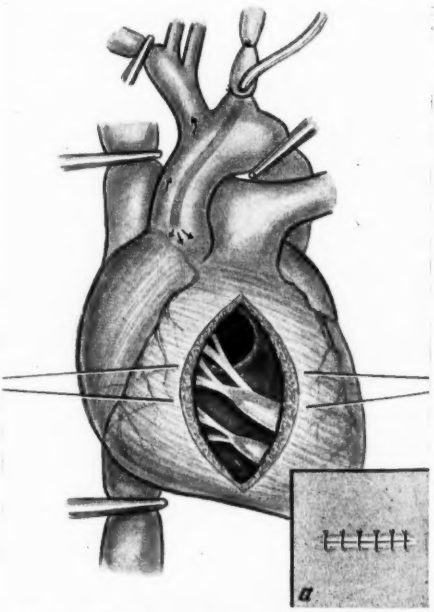

Fig. 1.—Drawing illustrating the exposure and repair (insert *a*) of ventricular septal defect.

TABLE 1.—*Repair of Ventricular Septal Defects Using Citrated Blood**

No. of Dog	Wt. of Dog, in Kg.	Temperature of Dog, in Degrees C	Time Caval Occlusion, in Min.	Blood Perfused, in Cc.	Ventricular Fibrillation	Duration of Defect	Final Result
223	13	25.5	28	620	Yes, arrested by simple massage	8 mo.	No brain damage Killed 73 days later
237	12.5	26.5	30	650	Yes	80 days	No brain damage Killed 61 days later
261	12	25.5	34.5	700	No	†	No brain damage Killed 34 days later
333	12	25	29.5	600	No	35 days	No brain damage Killed 60 days later
302	11	26	29.5	960	Yes	21 days	No brain damage Killed 40 days later
338	11	26.5	30	750	No	†	No brain damage Killed 40 days later
342	10.5	25.8	33	400	Yes, coronary embolism	†	No brain damage Killed 60 days later
325	12.5	26	32	600	No	20 days	Cardiac arrest during closure of chest; brain damage; clonic spasms; dead following day
355	9.5	26	32	780	No	†	No brain damage Killed 50 days later
357	9.5	27	30.5	800	Yes, arrested by simple massage	†	No brain damage Killed 48 days later

*Perfusion rate from 1.2 to 2.8 cc. per kilogram of body weight per minute.
†Made and closed during the time of perfusion.

There were 16 dogs in this series. In 10, citrated blood was utilized for the perfusion (Table 1). The temperature of the animals ranged between 25 C and 27 C, and the caval occlusion time between 28 and 34.5 minutes. The blood was perfused at the rate of from 1.2 to 2.8 cc. per kilogram of body weight per minute. A right ventriculotomy from 4 to 6 cm. long was made, and the defect was closed with from three to six interrupted silk sutures of 0000 intestinal silk (Fig. 1). In three animals, ventricular fibrillation developed after release of the venous inflow occlusion. In one, massive coronary embolism had been inadvertently produced by introduction of air through the perfusion catheter, the flask having been emptied of blood. Air was removed by cutting of several small coronary branches, fibrillation was strengthened by intracardiac epinephrine, and massage and electric defibrillation were successfully accomplished. In the other two dogs repeated blockade, calcium, and massage restored normal rhythm without electric defibrillation. In one of these two dogs procaine blockade had been inadvertently omitted before caval release. In all the animals in this group massage was first carried out after resumption of the circulation and was followed one minute later by the intracardiac injection of calcium.

One animal died the day after surgery after exhibiting clonic spasms and Cheyne-Stokes respirations. In this dog, unnoticed cardiac arrest had occurred sometime during repair of the chest wound. When the pupils were found fully dilated by the anesthetist, the chest was reopened and cardiac massage and intravenous infusion of a weak solution of epinephrine † restored excellent cardiac

†1 cc. in 500 cc. of 5% glucose.

contraction with immediate recovery but with evident brain damage. Such infusion of epinephrine was carried out afterward in almost all dogs perfused with citrated blood. The nine remaining animals recovered without any evidence of neurologic sequelae and were killed in from 34 to 73 days. In all, the defect was completely closed, and both the cardiotomy incision and the sutures in the ventricular septum were covered by smooth endothelium. In these dogs, the pupils never dilated more than half during the time of cardiac exclusion, and complete constriction was observed in all before repair of the chest wound was completed.

In six dogs ventricular defects were repaired during perfusion of heparinized blood (Table 2). The blood was administered at the rate of from 2.1 to 3.1 cc. per kilogram of body weight per minute, and caval occlusion lasted from 30.5 to 35 minutes. The body temperature was kept between 20.5 C and 26.5 C. In two instances coronary air embolism was observed after resumption of circulation. In one of these dogs ventricular fibrillation developed, and it was treated successfully in the usual fashion. In the other animal prompt section of four small coronary branches permitted the heart to be emptied of the air with resumption of a normal rhythm. In Dog 362, as the last of four sutures was tied to complete the closure of the defect, a 4 to 1 block developed. This stitch was rapidly severed and replaced, but the block persisted. Intravenous infusion of a weak solution of epinephrine was begun, and the heart was massaged, with prompt restitution of normal sinus rhythm. The dog recovered uneventfully but died the

TABLE 2.—*Repair of Ventricular Septal Defects Using Heparinized Blood**

No. of Dog	Wt. of Dog, in Kg.	Temperature of Dog, in Degrees C	Time Caval Occlusion, in Min.	Blood Perfused, in Cc.	Ventricular Fibrillation	Duration of Defect	Final Result
360	9.8	26.5	30.5	850	No	†	No brain damage Killed 25 days later
365	9.5	20.5	30	650	No	†	No brain damage Killed 26 days later
362	11	25.8	35	980	No	12 days	Died from massive hemothorax
363	11	26	32	930	No	20 days	No brain damage Killed 30 days later
395	11.5	26.5	30.5	900	Yes Air embolism	†	No brain damage Killed 25 days later
375	10.5	26	31	900	No	†	No brain damage Killed 27 days later

*Perfusion rate from 2.1 to 3.1 cc. per kilogram of body weight per minute.
†Made and closed during the time of perfusion.

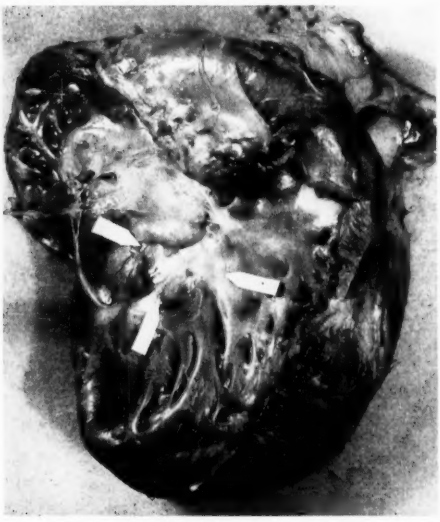

Fig. 2.—Photograph showing healing of repaired ventricular septal defect.

following day from massive hemothorax, the usual administration of protamine having been omitted through error. The other five animals survived indefinitely, and no sign of cerebral impairment was noted. They were killed in from 25 to 30 days following surgery. In all, closure of the defect was complete, and no thrombi were present in the heart (Fig. 2). In all of these animals the pupils had remained pinpoint in size during the cardiac exclusion.

terial silk (Fig. 3). In six animals citrated blood was used for the perfusion (Table 3). These dogs were operated upon at body temperatures ranging between 25 C and 26 C, and the time of caval occlusion ranged from 29 to 34.5 minutes. The perfusion rate was from 2.3 and 3.2 cc. per kilogram of body weight per minute. In none did ventricular fibrillation develop during the cardiac bypass. Three of these animals, however, developed ventricular fibrillation

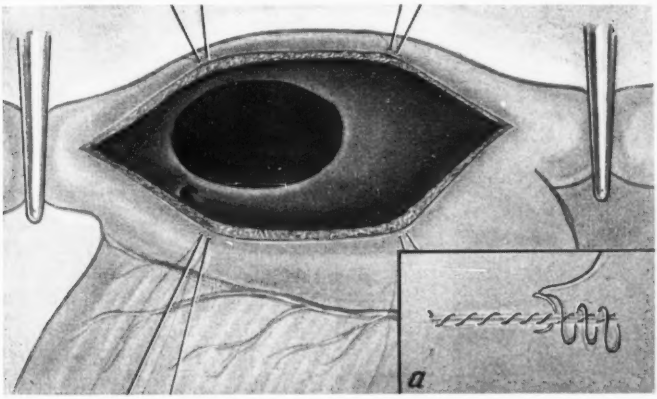

Fig. 3.—Drawing illustrating the exposure and repair (insert *a*) of atrial septal defect.

Animals with Repair of Atrial Septal Defect.—There were 12 dogs in this series. The right atrium was widely opened, carrying the incision over the upper part of the inferior vena cava. The defects were repaired with a continuous suture of 0000 ar-

after resumption of the circulation and following massage and intracardiac injection of calcium. In one of these three dogs procaine blockade had been omitted before caval release. In this and in another animal normal rhythm was restored by massage

TABLE 3.—*Repair of Atrial Septal Defects Using Citrated Blood**

No. of Dog	Wt. of Dog, in Kg.	Temperature of Dog, in Degrees C	Time Caval Occlusion, in Min.	Blood Perfused, in Cc.	Ventricular Fibrillation	Duration of Defect	Final Result
213	11	26	34.5	850	No	60 days	No brain damage Killed 35 days later
216	8	25.6	31	750	Yes	120 days	No brain damage Killed 50 days later
347	8.5	26	29.5	700	Yes	†	No brain damage Killed 30 days later
349	9.2	26	30.5	725	No	15 days	No brain damage Killed 34 days later
370	9	25	31	850	Yes	†	No brain damage Killed 35 days later
371	8.5	26	32	820	No	†	No brain damage Killed 40 days later

*Perfusion rate between 2.3 and 3.2 cc. per kilogram of body weight per minute.
†Made and closed during the time of perfusion.

and procaine blockade. In the third, electric defibrillation was successfully employed. All these dogs survived the procedure without exhibiting signs of cerebral impairment. They were killed in from 30 to 50 days.

Fig. 4.—Photograph showing closure of atrial septal defect.

In the remaining six animals heparinized blood was used for the perfusion (Table 4). Their body temperatures ranged from 25.5 C to 26 C, and caval occlusion time, from 28.5 to 32.5 minutes. The perfusion rate was from 0.9 to 3.9 cc. per kilogram of body weight per minute. In two, coronary air embolism was observed when circulation was restored. In one, fibrillation occurred before the air could be eliminated. In the other, three small coronary branches were rapidly incised and the air removed. Fibrillation did not occur in this animal. All these animals were rewarmed and survived indefinitely without any sign of brain damage. They were killed in from 12 to 40 days. In all, the defect was completely closed, and no thrombi were present in the heart (Fig. 4).

Very few reports have appeared in the literature concerning the experimental repair of cardiac septal defects under hypothermia and open surgery. Taufic and Lewis, who first used hypothermia for the experimental repair of ventricular septal defects, did not extend caval occlusion beyond 10 minutes.[10] They employed the same caval occlusion time in the repair of atrial septal defects.[11] Edwards and associates have recently shown that a ventriculotomy with production and closure of a defect can be accomplished safely with a low

TABLE 4.—*Repair of Atrial Septal Defects Using Heparinized Blood**

No. of Dog	Wt. of Dog, in Kg.	Temperature of Dog, in Degrees C	Time Caval Occlusion, in Min.	Blood Perfused, in Cc.	Ventricular Fibrillation	Duration of Defect	Final Result
222	9	26	29.5	480	No	105 days	No brain damage Killed 40 days later
382	7.5	25.5	32	750	No	†	No brain damage Killed 95 days later
386	7	26	31.5	300	Yes	†	No brain damage Killed 15 days later
366	8.5	25.5	28.5	500	No	55 days	No brain damage Killed 40 days later
394	6.5	26	31.5	750	No	†	No brain damage Killed 12 days later
215	10	25.5	32.5	860	No	90 days	No brain damage Killed 26 days later

*Perfusion rate between 0.9 to 3.9 cc. per kilogram of body weight per minute.
†Made and closed during the time of perfusion.

incidence of ventricular fibrillation during a 10-minute period of caval occlusion when the coronary arteries are perfused with oxygenated blood.[12] Other authors have also shown the beneficial effects of perfusing the heart, or the heart and the brain, during the time of venous inflow occlusion and open cardiac surgery.‡ We have demonstrated independently that coronary perfusion alone with oxygenated blood permitted a safe caval occlusion of from 25 to 30 minutes in moderately hypothermic dogs without evidence of persistent brain damage. When the coronary and carotid arteries were both perfused, caval occlusion could be maintained up to 40 minutes without neurologic sequelae.[7]

In these experiments the cause of death in a number of animals was due to hemorrhagic atelectasis and hemothorax. Gaertner and associates had the impression that chest bleeding alone was not the cause of death in their animals, but rather pulmonary congestion.[14] We have now apparently been able to prevent this complication by delaying the perfusion for two minutes after the beginning of venous inflow occlusion and by continuing respiration during this interval. In this fashion the lungs and the heart are largely emptied of blood before the perfusion is started, and hemorrhagic atelectasis has not been observed in this series of 28 experiments.

In the studies reported, both atrial and ventricular septal defects were repaired, or made and repaired, with almost uniform success. Important factors in these studies appear to be anesthetic blockade of the superior vena caval-atrial junction, perfusion of the coronary and carotid arteries with oxygenated blood, and prompt vigorous treatment of ventricular fibrillation and coronary air embolism when these complications developed.

In experiments performed without the aid of coronary or coronary and carotid artery perfusion by others and by us, the time of safe caval occlusion has been relatively short, probably too short for the repair of the more complex defects in the human heart. According to Lillehei and his group,[15] most of the ventricular septal defects in patients can, however, be repaired in less than 30 minutes, and usually in less than 20. Hypothermia and coronary and carotid artery perfusion with oxygenated blood, as we have employed it, would allow sufficient time for carrying out repair in most of the human cases. At present, it is not known whether the success obtained in experimental animals can be reduplicated in patients. Though atrial septal defects have been repaired during brief periods of caval obstruction, perhaps prolongation of the time of safe inflow occlusion by using the perfusion technique might be advantageous in some of the more complicated clinical cases.

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Summary

Coronary and carotid perfusion with oxygenated blood extends the safe period of venous inflow occlusion in hypothermic dogs and permits the repair, or the creation and repair, of cardiac septal defects with low mortality.

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Hypothermia in Open Heart Surgery

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The differences of opinion as to whether open or closed techniques in repair of congenital or acquired cardiac defects should be done is based primarily on the fact that the mortality rate has been higher in the open heart technique. It would seem that the development of simpler methods of artificial oxygenation will soon make the correction of cardiac defects possible with a very low mortality. Hypothermia as a means of allowing limited open heart technique has appealed to many because of its simplicity and availability.

In our own experience with hypothermia we have followed the lead of various excellent investigations into this problem. The early work of Fay,[1] Talbot,[2] McQuiston,[3] along with the experimental work of Bigelow and associates,* helped to point the way. There are many fundamental investigations that have been done in hypothermia as reviewed by Virtue.[8] Cookson and associates[9] repeated the work of Bigelow in dogs, and Bailey and co-workers[10] outlined their clinical experiences emphasizing the danger of air embolism and ventricular fibrillation. The repair of atrial septal defect has been accomplished successfully in a series of cases by Lewis and associates.† Swan and associates have done extensive work, both experimentally and clinically, in the use of hypothermia for open heart surgery.‡ They have used the technique in various congenital defects, with best results in isolated pulmonary stenosis and atrial septal defects.§ Scott[18] has also reported his observations with the use of hypothermia in cardiac surgery. Many others have also been investigating this approach.

The outstanding disadvantage of hypothermia is that ventricular fibrillation accompanies excessive lowering of the temperature, and there is danger of coronary air embolism where defects connect the right and left heart. Limitations of the time allowed for intracardiac surgery is also one of the inherent disadvantages of hypothermia. Although it seems certain that hypothermia as a method of allowing open heart surgery will be replaced by extracorporeal oxygenation of blood, at present there would still seem to be certain indications for this method. We have employed hypothermia in a large number of cases of great vessel surgery, but this report will deal only with a small series of open heart surgery under hypothermia. Of new interest in the material presented is the use of hypothermia to facilitate an open technique of alleviating aortic stenosis.

Technique of Hypothermia

The method of inducing hypothermia has been reported before and consists of the slow cooling by means of the "Thermorite" blanket and refrigeration unit.‖ This has the disadvantage of taking much longer to reduce the temperature while the patient is under anesthesia but has a very obvious advantage of being extremely easy to handle and requiring less manipulation of the patient. A moderate sedative is given the night before surgery, and preoperatively on the morning

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* References 4 through 7.

† References 11 and 12.

‡ References 13, 14, and 15.

§ References 16 and 17.

‖ Made by Thermorite Products, Inc., Buffalo.

of surgery 50 mg. of meperidine (Demerol) and atropine sulfate 0.4 mg. are given. Just prior to administration of the anesthetic, promethazine (Phenergan) or chlorpromazine (Thorazine) alone or in combination is given. Promethazine is given in doses as large as 25 to 50 mg. An intravenous solution of cold 5% dextrose in water is started with a 15 gauge needle, and quick induction of anesthesia is accomplished by the use of thiopental (Pentothal) and curare. The patient is intubated and then placed upon the blanket, and a second intravenous infusion is started. A second blanket is placed on top of the patient. The temperature of the circulating fluid is set at 4 C to 6 C. The anesthetic agent from here on is ether, but in extremely small quantities, and oxygen. The patient is observed as to tenseness of the muscles, and shivering is combated by administration of more promethazine or ether. The temperature of the body is recorded by means of thermometers in the nasal passages and in the rectum. The time required for reduction of the temperature to levels of approximately 90.5 F is one and a half to two hours. From here on, the temperature may fall quite rapidly, and by the third hour it has approached the level at which open heart surgery is possible, namely, 80.6 to 86 F. Surgery is started as the temperature passes 89.6 F. Reversal of the refrigeration blanket is done when the temperature is 86 F. Warming is continued slowly in the recovery room by means of hot water bottles.

Clinical Experience

Twelve cases have been operated upon during total occlusion of venous inflow into the heart under hypothermia. The range of body temperature measured rectally has been 77.9 to 86.0 F. Occlusion time has varied from three to nine and one-half minutes. Isolated valvular pulmonic stenosis and valvular stenosis with atrial septal defect, infundibular pulmonic stenosis, aortic stenosis, and atrial septal defect with aberrant pulmonary veins have been treated in this series as recorded in Table 1.

TABLE 1.—*Type of Cases*

Type of Defect	No. of Cases
Tetralogy of Fallot	4
Isolated pulmonary stenosis	2
Pulmonary stenosis and atrial septal defect	1
Infundibular stenosis and interventricular septal defect	1
Atrial septal defect and aberrant pulmonary vein	1
Aortic stenosis	3

Valvular Pulmonic Stenosis.—The advantage of direct visualization of the pulmonary valve over blind transventricular incision of the valve is probably more clearly felt in adult cases than in infants and children. It is our impression that the valve structure in the two patients appearing in this series, both of whom are adults, was tougher than that of children. Accurate incision with scissors under vision is likely to be more thorough than passage of a double-edged cutting blade of any type. The larger size of the structures concerned provides for ease of handling, particularly of the pulmonary artery.

The procedure in these cases was done through a median sternal incision, which in each instance provided a convenient exposure of the intrapericardial pulmonary artery. The superior and inferior venae cavae are isolated and prepared for temporary occlusion, and the pulmonary artery, in each instance dilated, is freed to a limited extent from adjacent structures and from the aorta. The artery is encircled with tape as far distally as is possible in preparation for clamp application. Before occlusion of the vessels is done, a suitable area on the anterior surface of the pulmonary artery near the valve is selected for longitudinal incision. Fine silk stay sutures are then placed, one on each side of the anticipated incision near its center. The venae cavae are then totally occluded and the heart allowed to beat two or three times before the pulmonary artery is cross clamped at the distal point previously prepared. The incision in the pulmonary artery is then made, extending longitudinally from a point near the valve ring for a distance of 2 cm. and passing between the silk stay sutures. Traction of the sutures opens up the incision, and the cone-shaped pulmonary valve is visualized. It is grasped with forceps and may be brought well up into the arteriotomy. Two or three incisions are made radially to the valve ring, after first amputating a short portion of the tip of the

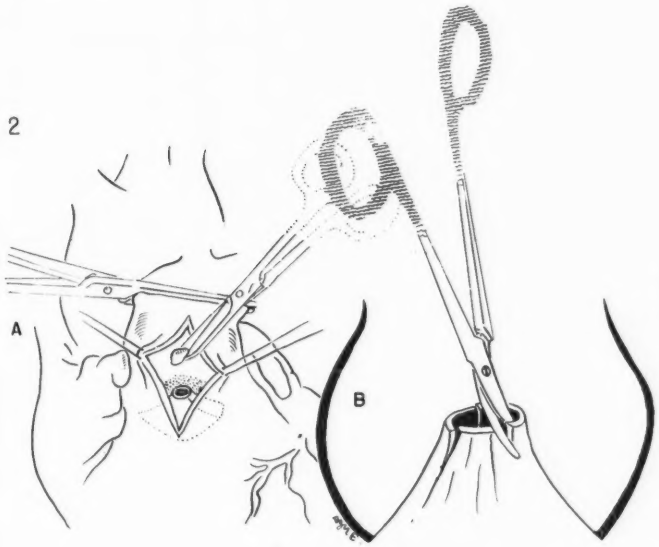

Fig. 1.—*A*, tip of cone-shaped valve is removed; *B*, radial incisions made in valve.

cone (Fig. 1). In one instance the fused cusps were observed to be quite well formed, and the suspensory structures of the cusps were present. In this instance it was believed that the incisions were made accurately in the commissures. Air is flushed out of the ventricle and artery with saline after digital exploration of the outflow tract of the right ventricle for an unsuspected deformity. The two sutures are lifted, and a curved artery clamp is placed on the incision in the artery in order that circulation may be restored and the repair done without hurry. The increase in pressure in the pulmonary artery does not have to be measured to be appreciated. In neither case has the thrill disappeared. In one it was more pronounced but of very much lower frequency. The comparative and postoperative pressure gradients in one of these cases are shown in Figure 2 (Table 2).

Infundibular Pulmonic Stenosis.—This lesion, rarely seen except with other associated defects comprising a more or less complete "tetralogy of Fallot," presents a debatable indication for any open operative procedure which falls short of complete correction of all defects. The success of vascular anastomoses for increasing pulmonary flow and the safety of the closed resection speak against increased risk in myocardotomy except for the purpose of restoring normal relationships. We were stimulated to try to effect a more thorough removal of the infundibular obstruction by failure to do a good job with the closed procedure. Of the five patients with infundibular stenosis in this series, two were examples of reoperation after failure by a closed operation. The pressure data and peripheral oxygen saturation preoperatively and after each procedure in one of these are presented in Table 3.

The approach to these patients was through a median longitudinal incision, and venae cavae preparation was the same as that described for valvular stenosis. The diagnosis of infundibular stenosis was confirmed by the demonstration of an infundibular chamber in each instance except one, in which the infundibulum was so high as to make the chamber insignificant. In all cases, including the one with a small chamber, the pulmonary artery was smaller than normal rather than dilated. The character of the obstruction was explored with a 4 mm. probe introduced through a small opening in the right ventricle below the infundi-

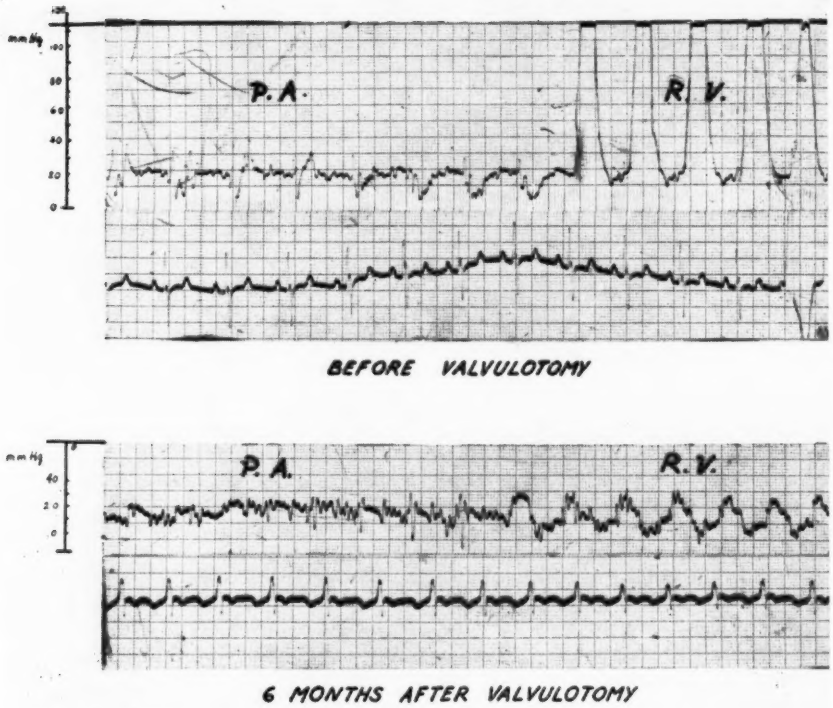

Fig. 2.—Pressure curves recorded by catheterization showing preoperative high right ventricular pressure with subsequent drop after valvulotomy.

TABLE 2.—*Valvular Pulmonic Stenosis—Case 1*
(Open Valvulotomy)

	Right Ventricular Pressure	Pulmonary Artery Pressure	Oxygen Saturation, Peripheral
Preoperative	140/46	12/6	92%
Postoperative	30/2-8	25/12	96.6%

TABLE 3.—*Tetralogy of Fallot—Case 4*
(Infundibular Stenosis)

	Right Ventricular Pressure	Pulmonary Artery Pressure	Oxygen Saturation, Peripheral
Blind resection			
Preoperative	100/5	10/0	90.6%
Postoperative	90/0	15/5	82.7%
Open resection			
Postoperative	90/0-12	30/10	92%

bulum. This opening was made between two rows of silk sutures placed to outline and control the planned longitudinal ventriculotomy wound. An excellent idea of the anatomy of the obstruction and the associated ventricular septal defect was obtained

in each instance with the probe. The cavae were then totally occluded, and the pulmonary artery was clamped to provide for cardiac occlusion. Concomitant obstruction of the aorta was carried out in two of the patients with the thought that a dry heart would not otherwise be obtained. In one of these coronary air embolism occurred, and aorta clamping has been avoided in subsequent cases. The possible mechanism of air embolism with the aorta clamped beyond the coronary orifices is a major concern in this procedure. With the clamp in this position on the aorta any air entering the right ventricle through the ventriculotomy wound will traverse the septal defect and, if momentary obstruction of either the septal defect or the right ventriculotomy wound is permitted, will be forced into the coronary orifices. The fact that flow of blood through the heart is interrupted does not affect this mechanism. The heart continues to function and during systole builds up pressure within the chambers if they are intact or if the wound or defect is obstructed. The single case in which the aorta was clamped along with the pulmonary artery developed air embolism. It seems possible that better technique would be to clamp only the pulmonary artery and depend on the aortic valve under some pressure from the elastic aorta to remain closed and keep the heart dry. Another suggestion has been made that the aortic clamp be placed low enough to occlude the orifices of the coronary arteries. In our dissections this seems to be difficult and unreliable.

It was mentioned that one of the reasons for undertaking open resection in the infundibular stenosis was some unsatisfactory results from closed procedures. The direct vision resection provides a means for complete relief of the obstruction, which is desirable in isolated infundibular stenosis but may be overdone in cases of tetralogy of Fallot. One such instance of reoperation has resulted in a marked increase in pulmonary artery flow, so that the effective left-to-right shunt is estimated on catheterization data to be about 15 liters per minute. At present and for a time in the future this patient is clinically much improved. The cyanosis is entirely eradicated. However, the right ventricular size has increased markedly and is anticipated to lead to failure. Some consideration is actually being given to the possibility of surgically obstructing the pulmonary artery in some degree. The catheterization data in this patient have been abstracted for Table 4.

Aortic Stenosis.—We have been particularly interested in the possible application of the technique in providing a means for direct visualization of the stenotic aortic valve. The median sternotomy incision provides an excellent approach to the vessel and has been used in three cases. In the first case, the circulation was totally occluded during manipulation of the valve, but a diverticulum of Dacron tube was first

TABLE 4.—*Tetralogy of Fallot—Case 5*
(Infundibular Stenosis)

	Vol. % Oxygen S.V.C.	Vol. % Oxygen P. A.	Right Ventricular Pressure	Pulmonary Artery Pressure	Oxygen Saturation, Peripheral
Blind resection					
Preoperative	13.8	16.5	97/7	12 (Mean)	94.2%
Postoperative	15.27	17.02	90/7	19 (Mean)	93.8%
(Systemic flow, 4.6 L./min.) (Pulmonary flow, 5.06 L./min.)					
Open resection Postoperative (Systemic flow, 2.39) (Pulmonary flow, 15.93)	12.5	18.16	88/11	17 (Mean)	98%

applied to the aortic arteriotomy edges because of distrust of the technique. Direct observation of the valve in this case was not obtained, but great ease of manipulation was experienced. Therefore, on two additional patients, after occlusion of the venae cavae and the aorta as far from the valve ring as possible, the aorta has been incised longitudinally and the edges of the wound retracted. The valve is immediately seen and its small orifice easily passed by any chosen instrument. Instead of using massive valve dilators we have used a 6 in. curved hemostat, which is small enough to be inserted into the smallest openings likely to be encountered and does not, because of size, obstruct the view (Fig. 3). In one instance the valve opened along two of the commissures to provide a large opening. In the second case directly visualized, the opening was not in an orderly fashion because of more extensive calcific changes. In the third case, not directly visualized, the opening was satisfactory but did not seem to be along the commissures. A definite impression is felt that the best available opening of the valve permitted by the character of the disease was obtained under vision. The question arises as to how much trauma is done to the area when larger instruments are passed before they can be opened to split the valve. Cutting with scissors as applied to the pulmonary valve did not seem practical because of the thickness of the diseased aortic valve.

A very serious consideration was given to the possibility of air embolism. This did not occur in the three cases presented. In one the area was protected from admission of much air by the Dacron cuff used, while in the remaining two air freely entered the basal aorta. It was, of course, not under pressure, and before pressure was reapplied, it was washed out with saline. Great care must be taken to fill the vessel with saline before the artery forceps is applied to the arteriotomy wound to approximate the edges for closure. Also, it is important to remove the clamp from the upper aorta before the venae cavae are released in order that any small amount of air may be moved on rather than injected under pressure into the coronaries.

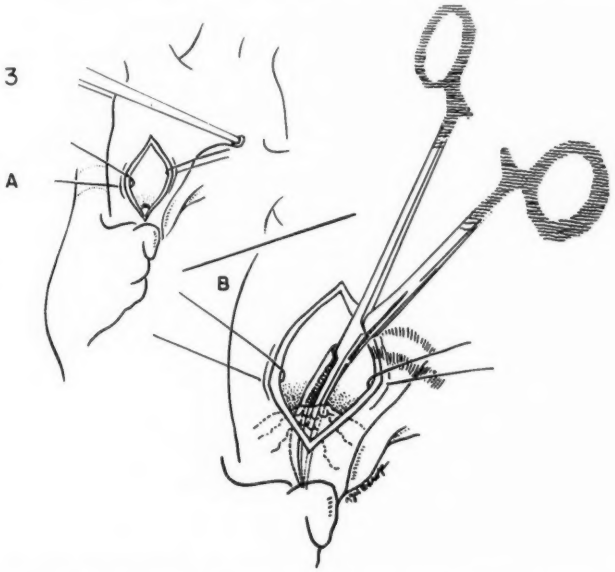

Fig. 3.—Valve being separated by curved 6 in. hemostat.

Interatrial Septal Defect.—The closed tactile methods of closure of atrial septal defect serve adequately for a majority of

cases. Additional means as provided by hypothermia and venous occlusion provide, according to some, an easier more accurate method. One instance of this method is included in this series. This was in an 8-year-old child having a large left-to-right shunt contributed to by an aberrant right pulmonary vein, in addition to the interatrial septal defect. Right thoracotomy provided exposure of the right atrium, which was opened widely after inflow occlusion of the cavae. No difficulty was experienced in closure of secundum defect with simultaneous directing of the aberrant vein into the left atrium. Since surgery the loud systolic murmur has disappeared, and a decrease in heart size and pulmonary vascular marking has been observed. Postoperative catheterization has not been repeated.

and reduction in right ventricular pressure have previously been referred to in Table 2. The results in these two cases were excellent.

Tetralogy of Fallot.—One of the four cases of tetralogy of Fallot had a valvular stenosis, and a valvulotomy was done through the pulmonary artery. This patient had very little overriding and has improved clinically. The second case of tetralogy of Fallot in a patient 27 years of age had an infundibular resection by the blind technique, and because of unsatisfactory results reoperation was done under hypothermia with open technique. The pressure readings are recorded in Table 3. This patient is markedly improved after the second operation, although none of her other defects were corrected. The third case of tetralogy of Fallot was also reoperated on after a

TABLE 5.—*Summary of Operative Results*

Case	Age	Diagnosis	Operation	Trapping Min.	Temperature Range, C	Result
1	16	Isolated pulmonic stenosis	Valvulotomy	6 1/2	28	Excellent
2	29	Isolated pulmonic stenosis	Valvulotomy	5 1/2	30	Excellent
3	17	Tetralogy of Fallot, valvular stenosis	Valvulotomy	8 1/2	28	Improved
4	27	Tetralogy of Fallot	Infundibular resection, reoperation	3	29	Improved
5	25	Tetralogy of Fallot	Infundibular resection reoperation	8	28.5	Unimproved
6	24	Tetralogy of Fallot	Infundibular resection	9 1/2	25.5	Ventricular fibrillation; died
7	32	Infundibular stenosis, interventricular septal defect	Infundibular resection	6	28.5	Air embolism; died
8	24	Infundibular stenosis, atrial septal defect	Infundibular resection	4 1/2	28.5	Improved
9	5	Atrial septal defect, anomalous pulmonary vein	Closure septal defect, rerouting	7	28.0	Excellent
10	70	Aortic stenosis	Valvulotomy	4	29.5	Unimproved
11	56	Aortic stenosis	Valvulotomy	4	28.0	Improved
12	41	Aortic stenosis	Valvulotomy	3	29.5	Improved

Results

The results of the 12 cases operated on with open heart technique under hypothermia are summarized in Table 5. The venacaval trapping time and the temperature range are also recorded.

Isolated Pulmonary Stenosis.—Two cases of isolated pulmonary stenosis have had a valvulotomy through the pulmonary artery with open technique with gratifying results. The increase in pulmonary artery pressure

previous blind resection, and, as was noted before, has had an increase of pulmonary blood flow and is unimproved (Table 4). The fourth patient died after infundibular resection from excessive hypothermia followed by ventricular fibrillation.

Infundibular Stenosis with Interventricular and Atrial Septal Defect.—One case with infundibular stenosis and interventricular septal defect had an infundibular resection, and during operation air embolism occurred followed by ventricular fibrillation

and death. One patient with infundibular stenosis and atrial septal defect had an infundibular resection and has shown improvement.

Atrial Septal Defect with Anomalous Pulmonary Venous Return.—This patient had an atrial septal defect of the secundum type which was closed with the open technique, and the anomalous left pulmonary vein was rerouted into the left atrium along with the closure of the defect. The result in this patient was excellent. This patient is cured clinically, with disappearance of the murmur.

Aortic Stenosis.—On exploration of the use of the open technique in aortic stenosis, three patients had aortic valvulotomy from above. One was with the addition of a Dacron pouch with trapping, and the other two with the aorta open at the time of valvulotomy. No air embolism occurred in these two latter patients, and two of these patients have shown improvement and one is unimproved.

Comment

Only a broad impression may be obtained from a series of this small size. However, it is of some help as a guide for future use of this method. The greatest satisfaction obtained has been in isolated valvular pulmonic stenosis, where the condition is in a sense cured and the pressure values obtained with catheterization show a near return to normal values. The anatomical results in atrial septal defects of the secundum type are anatomically good. The results in this method in opening up a stenosed aortic valve are encouraging and are probably as good as can be obtained in the severely deformed valve of aortic stenosis. A disadvantage in aortic stenosis would seem to be the possibility of air embolism, although this did not occur in the few cases that were done. This procedure is being explored both experimentally and clinically and is not at this time recommended as a procedure of choice for aortic stenosis. In atrial septal defects, the fact that closed methods of Bailey,[19] Björk,[20] Gross,[21] and others[22] can successfully be applied should be emphasized. This applies even with associated aberrant pulmonary veins. The distinct disadvantage of using the open technique in infundibular stenosis is the fact that infundibular stenosis is usually associated with other defects. Occasionally, however, it is an isolated lesion.[23] The fact that the other defects are not corrected at the time infundibular resection is done is a real objection to this method. The danger of air embolism would seem to be marked in the presence of interventricular septal defects. This occurred in one of the four cases of infundibular resection, resulting in death. As was pointed out in Table 4, too complete a resection of the infundibular stenosis may be detrimental.[24]

Summary

The results of using open heart technique under hypothermia in nine cases of congenital heart disease and three cases of acquired valvular heart disease are presented. There were two deaths, one from air embolism and the second from ventricular fibrillation from excessive hypothermia. Acquired valvular heart disease, namely, aortic stenosis, has been approached by the open technique through the aorta. This is only in the exploratory stage.

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DISCUSSION

ON PAPERS BY DRS. HELMSWORTH AND COLE; RIBERI AND KAJIKURI; AND JULIAN, DYE, GROVE, SADOVE, AND COELHO

DR. HENRY SWAN, Denver: I should like to confine myself to two comments.

Dr. Helmsworth and Dr. Cole's work I consider as being doubly important. For example, a disturbance in the clotting mechanism has been the major cause of death in our experience in 105 open heart operations. Thus, I think that an intense study of this phase of hypothermia is extremely desirable.

Second, they have made a clear-cut demonstration, I believe, that the technique of inducing hypothermia alters the eventual physiologic state which is achieved. There is a difference apparently in what happens to the formed elements of the blood, depending on whether you use external or internal cooling methods.

Thus, techniques for hypothermia should not eventually be chosen on the grounds of convenience or esthesics, but on sound physiologic understanding of what is achieved.

I also should like to congratulate Dr. Dye, Dr. Julian, and their group on their early success with open heart surgery. Vision in all surgery is extremely important.

[Slide] This is the only operation for pulmonary valvular stenosis which has consistently effective results. At a recent meeting the discussion brought out that there are now known 52 operations by six different surgeons which have been performed in this fashion, without a single mortality. I think that even Sir Russell Brock will soon have to admit that it is a relatively safe as well as a completely effective procedure.

[Slide] When applied to the aortic valve, the reason that air does not enter the coronary arteries, I believe, is because the coronary veins do not have valves. Muscle action of the myocardium, therefore, does not propel blood along the major coronary arterial system and thus allow air to enter the coronary ostia during the open portion of the procedure.

As you see, we have felt that multiple clampings are desirable in this particular approach;

but the purpose of all these is to allow the left ventricle and then the aorta to fill, from below upward, with blood which you release into the left side of the heart from the lung, thus taking great care not to trap any air in the aorta during the escape maneuver.

This technique, as Dr. Dye said, does give very adequate (although not perfect) exposure of the aortic valve in man for operative manipulation, but the valve pathology still offers serious problems.

DR. JOHANN L. EHRENHAFT, Iowa City: We do not have the large experience as presented by by Dr. Swan just now, but we have gained experience in 24 patients in whom we used hypothermia for exploration and correction of different intracardiac and extracardiac lesions. Of the 24 patients, 19 had interauricular septal defects of one type or another. In spite of all the excellent diagnostic procedures available at the present time, we still have difficulty at times in differentiating ostium primum from ostium secundum type defects of the interauricular septum. We also have noted the very high incidence of other associated intracardiac or extracardiac great vessel lesions. We have induced hypothermia using an ice bath and inducing cooling in a rather rapid manner. This method has worked very satisfactorily for us.

Of the total number of 24 patients, 10 developed ventricular fibrillation during the procedure. We have converted ventricular fibrillation by electric shock in all instances and have not relied upon other methods as, for instance, neostigmine (Prostigmin), potassium, or procaine (Novacaine) for blockage of the sinoauricular node.

We believe that all patients with interatrial septal defects should be explored, but in patients with ostium primum type defects we have attempted closure in only a few. As you can see from Table I, only one patient out of three survived after closure of an ostium primum defect, whereas no patients died if the defect was not closed and the lesion only explored.

In the group of patients with ostium secundum type defects (Table II), two patients died after closure, death being due to cardiac failure postoperatively and pulmonary hypertension.

TABLE I.—*Ostium Primum Type Defects*

	No. of Patients	Died
Closed (one with aortic coarctation)	3	2
Not closed (one with anomalous coronary sinus and left superior vena cava)	3	0
Common atrioventricular canal	1	1
Total	7	3

TABLE II.—*Ostium Secundum Type Defects*

	No. of Patients	Died
Without other anomalies	8	0
With partial anomalous venous return	1	0
With patent ductus arteriosus and pulmonary hypertension	1	1
With severe pulmonary hypertension and cardiac failure	1	1
With pulmonary valvular stenosis	1	0
	12	2

TABLE III.—*Other Lesions*

	No. of Patients	Died
Pulmonary valvular stenosis	2	0
Aortic arch anomalies and aortic stenosis	1	0
Coarctation of aorta (corrected) and interventricular septal defect	1	0
Repair of coarctation of aorta (no collateral circulation)	1	0
	5	0

Total number of patients 24
Ventricular fibrillation 10

In addition, we treated five patients with varied types of lesions as shown in Table III.

DR. WILLIAM O. MCQUISTON, Peoria, Ill.: I should like to sound a word of caution on the use of hypothermia. We have now used hypothermia, moderate hypothermia, or normothermia in well over 1000 cases since 1948, and we would suggest that radical hypothermia should be used with great caution and should be limited to open cardiac surgery. Low temperatures are neither indicated nor advisable for most cardiac operations.

One should attempt to discover the highest temperature that will protect the vital centers, not the lowest temperature at which life can be sustained.

There seems to be a tendency today to administer many anesthetic drugs to a point just short of a lethal dose in order to give the surgeon an optimal field. We reduce blood pressure just short of death. We give curare for relaxation just short of death.

I like an occasional complaint from the surgeon about a tight belly. If the surgeon does not complain, I wonder if I haven't given too much anesthetic. The complaint about a tight belly is nothing as compared to the complaint from a cardiac arrest.

Mitral Valve Surgery and Left Heart Catheterization in Giant Left Atrium

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and
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The finding of a giant left atrium is commonly considered as evidence of predominant mitral regurgitation.* As such, this would contraindicate mitral stenosis surgery. However, in a series of 153 left heart catheterizations we have encountered 14 such patients. In five patients mitral stenosis was the dominant or sole lesion, and surgery was performed in these cases, with confirmation of the preoperative diagnosis.

The frequent recording of severe vibratory pressure fluctuations in the left atrium in these patients is of interest in a consideration of the nature of massive left atrial enlargement.

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From the Division of Thoracic Surgery, University of Pittsburgh, School of Medicine, and the Cardiopulmonary Laboratory, Allegheny General Hospital.

* References 1 and 2.

Procedures

All 14 patients with giant left atrium had a careful history, physical examination, roentgenographic and fluoroscopic evaluation of heart size and chamber enlargement, electrocardiogram, urinalysis, complete blood cell count, and appropriate blood chemistry tests. Transthoracic left heart catheterization was done in the prone position, with intermittent fluoroscopic observation for guidance of needle insertion into the left atrium from the right paravertebral approach.[3] By this technique it is possible to determine the degree of mitral stenosis and regurgitation which may be present. The criteria used for this determination are listed in Table 1. Mitral stenosis is proportional to the pressure difference between the left ventricle and atrium during diastole. Figure 1 illustrates a pressure recording in Patient 4, with severe mitral stenosis. Mitral regurgitation is illustrated in Figures 2 and 3, with great increase of left atrial pressure (tall V-wave) following the C-wave.

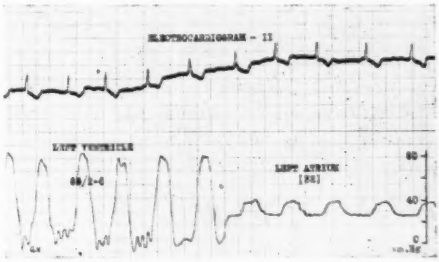

Fig. 1. (Patient 4).—Pressure recording during catheter withdrawal from left ventricle to left atrium, showing 20 mm. Hg mitral stenosis effect with no evidence of mitral regurgitation.

TABLE 1.—*Criteria for Severity of Mitral Insufficiency and Mitral Stenosis*

	Severity				
	0	1+	2+	3+	4+
Mitral insufficiency (or incompetence) effect (left atrium V-wave height minus C-wave height, mm. Hg)	0-3	4-6	6-8	8-10	10+
Mitral stenosis effect (left atrium mean pressure minus left ventricle early diastolic pressure; minus mitral insufficiency effect) (LV early diastolic pressure immediately follows the initial diastolic dip)	0-3	4-6	6-10	10-15	16+

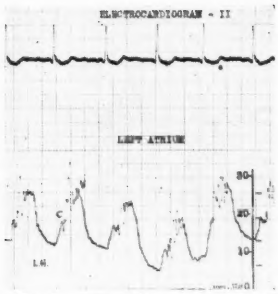

Fig. 2 (Patient 7).—Pressure recording from left atrial needle, showing 13 mm. Hg mitral regurgitation effect (V-C) with marked vibrations discussed in text.

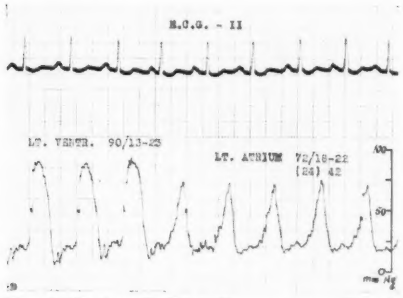

Fig. 3 (Patient G. B.).—Pressure recording during catheter withdrawal from left ventricle to left atrium as an example of extreme mitral regurgitation in a patient without giant left atrium.

Results

All 14 patients gave a history of progressive severe disability. Functionally, 10 were classified in Group III and four were in Group IV.[4] All had large hearts with giant left atria by x-ray (Figures 4 and 5). Apical systolic and diastolic murmurs were present in each case. A loud or split P_2 was heard in all cases. Electrocardiogram in each case revealed atrial fibrillation without evidence of predominant left or right ventricular hypertrophy, except in Patients 8 to 11, in whom left ventricular hypertrophy was found. The results of pressure recordings at the time of left heart catheterization are given in Table 2.

Five patients had findings characteristic of predominant mitral stenosis, and they were therefore operated upon. The operative findings agreed with the left heart studies, as indicated in the Table (Patients 1 to 5). Four of the five patients survived surgery and have had a favorable postoperative course for six, five, seven, and five months, respectively. Patient 5 died postoperatively of intractable right heart failure, following simultaneous mitral and tricuspid commissurotomy. Preoperatively she had been classed in functional Group IV.

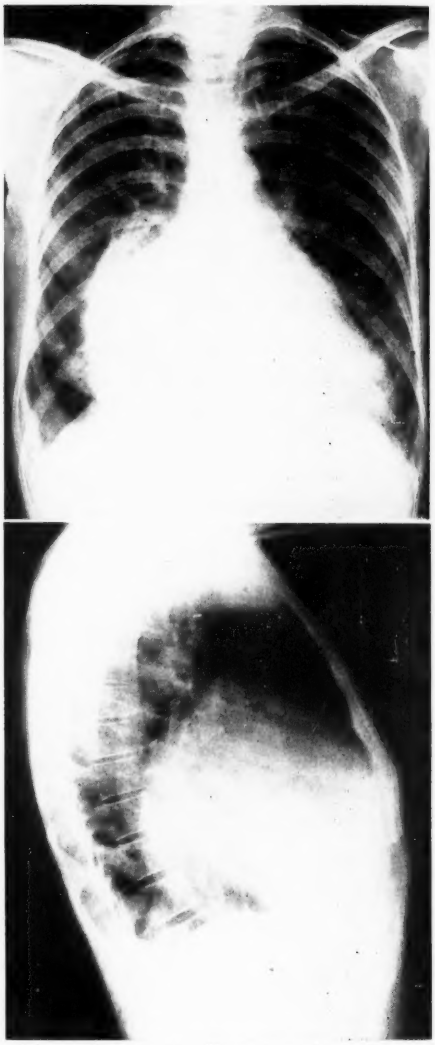

Fig. 4 (Patient 1).—Posteroanterior and lateral x-rays of patient with giant left atrium, successfully operated on for mitral stenosis.

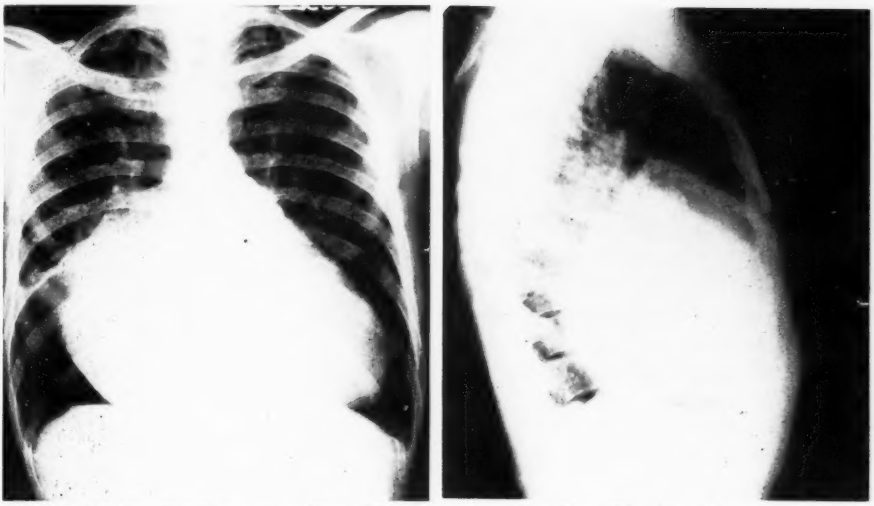

Fig. 5 (Patient 2).—Posteroanterior and lateral x-rays of patient with giant left atrium, successfully operated on for mitral stenosis.

TABLE 2.—*Results of Pressure Recordings During Left Heart Catheterization*

	Functional Class	Left Heart Catheterization Results, Mm. Hg					Surgical Diagnosis	
		L.A., mean	L.V.	Aorta	M.S. Effect	M.I. Effect	M.S.	M.I.
1*	III	27	.....	.....	.....	3.5 (1+)	4+	2+
2	IV	25	128/6-9	130/64	19 (4+)	2 (0)	4+	0
3	III	26	.....	.....	.....	4 (1+)	4+	2+
4	III	32	85/2-6	83/57	29 (4+)	1 (0)	4+	0
5*	IV	19	106/3-8	109/75	11 (3+)	5 (1+)	4+	2+
6	IV	31	.....	.....	.....	21 (4+)	No surg. performed	
7*	III	18	126/3-7	121/69	2 (0)	13(4+)	No surg. performed	
8	III	25	110/10-14	.....	0 (0)	20 (4+)	No surg. performed	
9*	III	20	118/1-10	118/70	3 (0)	17 (4+)	No surg. performed	
10	III	14	116/10-11	125/78	0 (0)	8 (3+)	No surg. performed	
11*	III	21	115/7-11	112/76	8 (2+)	6 (1+)	No surg. performed	
12	III	23	159/3-5	.....	12 (3+)	8 (3+)	No surg. performed	
13	IV	36	.....	.....	.....	7.5 (2+)	No surg. performed	
14*	III	30	.....	.....	.....	9 (3+)	No surg. performed	

* Patients demonstrating marked pressure vibrations discussed in text.

Five patients (Patients 6 to 10) were shown by pressure recordings to have only mitral regurgitation. Surgery was not offered to these patients.

One patient (Patient 11) had mild mitral stenosis and regurgitation but was primarily in difficulty owing to left heart failure, presumably due to myocardial disease. This case illustrates the value of the procedure in differentiating myocardial disease from severe valvular disease.

Two patients (Patients 13 and 14) should be retested for left ventricular pressure recordings to determine the degree of mitral stenosis. Their tests were done early in the series of left heart catheterizations, when left ventricular entry of the catheter could not be done routinely.

Comment

The cause of extreme left atrial dilatation has not been established. Several theories have been advanced in explanation. Although inflammatory or degenerative disease of the atrial muscle has been postulated as an etiological factor, no convincing evidence has been found.[1] The level of mean left atrial pressure bears no correlation to the development of a giant left atrium; the pressures recorded in the patients in the present series are in the same range as in comparable patients without giant left atrium.

Mitral regurgitation per se is not the causative factor, since there was no regurgitation present in Patients 2 and 4. Three patients (Patients 1, 3, and 11) had only slight mitral regurgitation, and two had mild regurgitation (Patients 5 and 13). On the other hand, extreme mitral regurgitation may be represented by a patient with a left atrial pressure almost equal to his left ventricular pressure, who did not have a giant left atrium (Figures 3 and 6). Neither is mitral stenosis a prerequisite for the development of a giant atrium, as evidenced by Patients 6 to 10, who have pure mitral regurgitation.

An unexpected observation has been the frequent recording, in 6 of the 14 cases, of violently fluctuating pressure vibrations (Figure 2). These have a frequency of about 37 cps and may reach an amplitude of 12 mm. Hg. These vibrations occur after the time of mitral valve closure, during ventricular systole. Artefacts have been eliminated as the cause of the vibrations by recording from the left atrial needle, with

Fig. 6 (Patient G. B.).—Posteroanterior and lateral x-ray of patient with severe regurgitation without giant left atrium.

the needle lumen lying free within the left atrial chamber, at a distance of 1 cm. or more from both the anterior and posterior atrial walls, respectively. The frequency response of the system when recording through the needle is uniform to about 50 cps, without resonant peaks. Catheter recordings were not used in the study of these vibrations, since the vibrations would be damped out by recording through the catheter and motion artefacts in catheter tracings might invalidate the observations.

These left atrial pressure vibrations might be transmitted from vibrating valve cusps, left atrial walls, or left ventricular walls. They could also result from the fortuitous positioning of the needle orifice within a regurgitant jet, but this seems unlikely, since they have been observed only twice in a series of 139 patients having mitral valve disease without giant left atrium. Of these two patients, one has since died at home, with no autopsy, and the other is being observed for increase in size of the left atrium.

The generally favorable results of surgery for mitral stenosis in this group of patients with giant left atrium do not differ from those obtained in comparable patients without extreme left atrial dilatation. All of the patients operated on were severely handicapped, with long histories of progressive disability. Functionally, they were all in Group IV or far-advanced in Group III. Atrial fibrillation was present in all. None of these patients would have been offered surgery if standard clinical criteria had been accepted. There are no clinical criteria which are reliable in establishing the predominant lesion when the physical signs of both mitral stenosis and insufficiency are present. Therefore, left heart catheterization should be performed on all such patients, so that no eligible patient will be denied the benefits of surgery.

Some modifications of the standard left heart catheterization procedure are helpful in passing the catheter through the mitral valve in patients with giant left atria.[5] These include repeated insertions and withdrawals of the catheter through the left atrial needle from various directions, careful observation of the pressure contour on an oscilloscope for the occurrence of valve impact artefacts, the use of two or more catheters of varying degrees of flexibility, and various changes of needle position in relation to the valve orifice. Prolonged, persistent manipulation is made possible by adequate sedation.

Summary and Conclusions

Mitral stenosis is frequently the predominant valve lesion in patients with giant left atrium.

Left heart catheterization is usually necessary to establish the correct diagnosis of the valve lesion, since the clinical diagnosis may otherwise be incorrect.

Properly selected patients with giant left atrium benefit from surgical relief of a predominant mitral stenosis. The results of mitral commissurotomy in the presence of a giant atrium are comparable to those obtained in patients with the usual degree of left atrial enlargement.

Severe left atrial vibratory pressure fluctuations have been recorded in cases of giant left atrium.

The cause of extreme left atrial enlargement has not been established.

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Causes of Death in One Thousand Operations for Congenital Heart Disease

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and
THOMAS G. BAFFES, M.D., Chicago

Introduction

To February, 1955, one thousand operations were performed for many types of congenital heart disease in children from ages 8 days to 16 years. There were 90 deaths and 89 postmortem examinations. It seemed to us that an inventory of the causes of death during and immediately following operation might be of considerable value to us and of some interest to those concerned with the surgical treatment of congenital heart disease.

Reference to Table 1 will at once reveal the well-known fact that certain abnormalities are associated with extremely high mortality. Our primary interest in this study has been to learn which of the deaths were preventable. It is often a bit disillusioning to turn the spotlight of postmortem finality on operative deaths. Very frequently, however, after postmortem examination, it was still impossible to say which

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From the Children's Memorial Hospital and Northwestern University Medical School.

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TABLE 1.—*Deaths in One Thousand Operations for Congenital Heart Disease*

	Number	Deaths	Mortality, %
Cyanotic group			
Tetralogy of Fallot			
8 days to 3 years	196	30	15.3
3 years to 16 years	220	8	3.6
Tricuspid atresia			
13 days to 3 years	24	5	20.8
3 years to 16 years	8	0	0.
Isolated pulmonary stenosis			
23 days to 16 years	61	1	1.6
Totals	509	44	8.6
Exploratory	36	15	42.0
Transposition of the great vessels	15	13	86.0
Noncyanotic group			
Patent ductus arteriosus			
28 days to 16 years	347	0	0.
Coarctation of the aorta	52	2	3.8
Anomalies of the aortic arch	25	6	24.0
Interatrial septal defect	5	1	20.0
Miscellaneous group	11	9	81.0
Grand totals	1,000	90	9.0

particular pathologic change was the cause of death. For example, a puny, 12 lb. 6-month-old deeply cyanotic infant having had an aortic-pulmonary anastomosis for tetralogy of Fallot dies 48 hours after operation. Postmortem findings are as follows: petechial hemorrhage in the basal ganglia of the brain, mild bilateral bronchopneumonia, congestion of the lungs; the usual deformities in the heart; a patent anastomotic channel between the aorta and pulmonary artery. Try to pin the pathologist down to a simple cause of death and he refers the surgeon to a lengthy report of microscopic findings in each organ. It has been with considerable restraint that we avoided a column labelled "just died" and as conscientiously as possible assigned one cause to each of the deaths.

The Cyanotic Group

Although there were 72 deaths in this category, of greatest interest are the 44 deaths (Table 2) which occurred in children whose cyanosis was remediable by more or less accepted surgical procedures. To bring the causes of death into clearer focus and to distinguish the preventable from the nonpreventable, these cases will be discussed under separate headings.

TABLE 2.—*Cause of Death in Cyanotic Group Remediable by Surgery*

	Cases, No.
Brain damage	9
Heart failure	7
Lung complications, preoperative and postoperative	7
Blood loss and shock	6
Occlusion of ductus arteriosus during anastomosis	5
Postoperative infection	3
Too large anastomosis	3
Improper procedure	2
Embolus	1
Thrombosis of anastomosis	1
Total	44

Brain Damage.—Cerebral hemorrhage, or thrombosis, was the obvious cause of death in seven patients and the likeliest cause in two. Three of these children had cerebral accidents prior to surgery. A considerable number of children had cerebral accidents prior to surgery but survived. The one postmortem examination not allowed was in one of the children who died of presumed hemorrhage into the pons. Six of the nine patients who died of brain damage were operated upon before hypothermia was introduced in 1948. Although we have only limited statistical evidence that hypothermia —temperatures of 85 to 95 F during operation—lessens the dangers of brain damage during operation, we are convinced that moderate reductions in temperatures are decidedly beneficial.

Heart Failure.—Seven children died of heart failure following operation. One death of typical heart failure occurred 14 days after surgery in a one-year-old child with tricuspid atresia. Of particular interest are the six with tetralogy of Fallot who died 24 to 72 hours after operation, all with rather similar clinical and pathologic findings. Preoperatively, there was no reason to suspect a fatal outcome. The operation went well, a functioning anastomosis was established, and the child was returned to his bed in good condition. Within a relatively few hours the child's color became dusky, grunting respiration was noted, the pulse became weak, the liver became palpable, and death occurred. At postmortem examination the outstanding finding was bloody congestion of the lungs. In fact, the lungs were flooded and soggy as a marsh. In a few instances there were old thrombotic changes in the arterioles of the lungs. We have never been able to explain why this syndrome appears in one child and not in others following shunt operations, in all of which the anastomotic channels are the same size.

Blood Loss and Shock.—Blood loss and shock caused six deaths. Three of these were preventable. The first was due to ignorance. In 1947 we believed that moderate bleeding during surgery might be beneficial for the cyanotic child with a very high red blood cell count and that plasma was the volume substitute of choice. This case corrected that false opinion: After completion of an aortic-pulmonary anastomosis on a 6-year-old boy there was sudden and

marked fall in blood pressure. The blood pressure improved momentarily following intravenous administration of plasma but again fell precipitously. Blood was then given, but too late, and the child died of typical shock. Since then, it has been routine to replace blood loss with blood regardless of the degree of cyanosis. Cyanotic children develop hemoconcentration to satisfy the oxygen wants, and to dilute their blood with plasma is unphysiologic.

The second death was due to inattention. A 12-year-old boy died of hemorrhage 15 hours after operation. The parents wished the "best possible care" and insisted on three special nurses. The night nurse noted the rise of red fluid in the drainage bottle but did not appreciate its significance until the pulse became weak and thready. We were probably to blame for not giving the nurse detailed instructions about the importance of reporting a rise in the fluid level in the drainage bottle. A rapid, forced emergency transfusion at 5 a.m. was too late. At postmortem examination an open intercostal artery was found. Now all postoperative heart patients are kept on one floor in one of two four-bed wards, and they are cared for by specially trained nurses and student nurses until it is safe to move them to private rooms, if desired. Parents who are accustomed to private room accommodations accept this routine graciously when it is explained that observation by nurses experienced in cardiac nursing is more important than the frills of hospital care.

The third death was due to poor judgment. Massive hemorrhage occurred in the wound after operation. Pressure dressings were applied and changed without realization of the amount of blood loss. When finally the chest was reopened in an attempt to find the source of bleeding, death from shock occurred.

Death was due to rupture of the left pulmonary artery distal to an aortic-pulmonary anastomosis in one case. One patient died 24 hours after operation from hemorrhage during and following infundibulectomy.

The cause of the sixth death is still a matter of dispute. A 2-year-old child with isolated pulmonary stenosis, severe cyanosis, and marked cardiac enlargement was given intravenous procaine, cyclopropane, and oxygen. During instrumentation the heart became slow, then stopped. It was massaged a couple of times and promptly started beating. Considerable loss of blood occurred. The heart stopped again and after injection of epinephrine (Adrenalin) resumed beating. As the pericardium was being closed, the heart went into ventricular fibrillation and the child died. Cause of death: hemorrhage? cardiac arrest? drugs? It is the one case of possible cardiac arrest referred to later. It is listed under hemorrhage by majority vote. We have not used intravenous procaine since.

Lung Complications.—Lung complications, such as pneumonia and purulent tracheobronchitis, were the causes of death in seven children. It is difficult to know whether these infections were secondary to or aggravated by intubation. Twice we exercised poor judgment in choosing the time of operation. Two children, both infants, had recognized slight upper respiratory infection before operation. Because of their urgent need for surgical relief and because they came from long distances, we lowered our guard and consented to operation. Both had large doses of penicillin before operation; both developed pneumonia and died. A fact learned later, that in one instance the child in the adjoining bed received the penicillin, probably had little to do with the outcome.

Postoperative Infections.—These accounted for three deaths: One was due to septicemia secondary to septic thrombophlebitis in the saphenous vein at the site of the cutdown, and one was due to purulent pericarditis—source of infection unknown. The third death from infection was a tragedy readily explainable. This child was operated upon in 1949 during a convention

of surgeons in Chicago. By actual count there were 29 visitors milling about in the operating room during a very difficult operation requiring approximately three hours. Death from an overwhelming streptococcal pleuritis of the left lung occurred 49 hours after operation.

Occlusion of a Patent Ductus Arteriosus.—Such occlusion of the only source of blood to the lungs in very cyanotic patients with pulmonary atresia accounted for four of the deaths during the anastomosis and was the presumptive cause of death in the fifth. Postmortem examination in all five cases showed atresia of the pulmonary artery and a patent ductus arteriosus of insufficient size to provide adequate oxygenation but large enough to sustain life. The ages of these patients were 8 days, 3 years, 4 years, 6 months, and 6 months. Four of these patients died on the operating table. In each instance the pulmonary artery was very small but large enough for an aortic-pulmonary anastomosis. After the vessels were occluded, the pulse promptly slowed, and before the anastomosis could be completed death from anoxia occurred because the life line, the ductus, was occluded by the aortic clamp, and/or by the ligatures temporarily occluding the pulmonary artery. The fifth child died two days after operation without regaining consciousness. Her heart practically stopped during the anastomosis, and at postmortem examination it was found that the only source of blood to the lungs had been the ductus arteriosus. At present, when the pulmonary artery at operation is very small and a patent ductus is suspected of being functional, we use a curved toothed clamp placed tangentially on both the aorta and the pulmonary artery and thereby avoid disturbing the region of the ductus arteriosus.

Too Large an Anastomosis.—Too large an anastomosis was made three times. In two instances a subclavian artery approximately 6 mm. in diameter was anastomosed to the pulmonary artery. Death from pulmonary edema and congestion followed in these two cases in less than 24 hours. The third child had an aortic-pulmonary anastomosis 6 mm. in diameter. Death from heart failure and pulmonary congestion occurred on the 14th day after operation. Only at postmortem examination was the huge anastomotic channel found and presumed to be the cause of death.

Recently, after a subclavian-pulmonary anastomosis, signs of too much blood to the lungs were recognized and six hours after operation the chest was reopened and the anastomosis was partially closed. The child recovered.

Various Causes.—These accounted for four deaths. In one instance thrombosis occluded a poorly made anastomosis of the subclavian artery to the distal end of a small left pulmonary artery. In another we attempted an infundibulectomy in a child who at postmortem examination was found to have a tubular type of infundibular stenosis which had not been properly opened at operation. After an aortic-pulmonary anastomosis on the right side a clot formed at the anastomotic site and an embolus broke off and occluded the aorta at its bifurcation. The child died following embolectomy. The fourth of this group, an infant with tricuspid atresia, died 15 days after operation from occlusion of an aortic-pulmonary anastomosis by thrombosis.

Explorations

Although the chest was merely opened, the region of the hilus of the lung explored, and often the pericardium opened, nevertheless 15 of 36 patients died after exploratory operation. The majority were cyanotic, and 10 of these had atresia of the pulmonary artery or an artery so small that no anastomosis was possible. Nine died of anoxia and one of purulent bronchitis. It has always been our policy to explore children whose condition appears hopeless without surgical relief. Occasionally, in spite of a gloomy preoperative prognosis, a shunt operation can be accomplished with a satisfactory result.

Five children with transposition of the

great vessels died after simple exploration. Hypoxia and heart failure were the primary causes of death.

Transposition of the Great Vessels

To February, 1955, fifteen patients with transposition of the great vessels were operated upon and thirteen died. Since then, one of the remaining two has died. The majority died within a few days or weeks after operation, the causes of death being continued cyanosis and heart failure. We attempted most of the procedures suggested by other authors and a couple of our own. Discussion of these deaths, all nonpreventable with the methods used, seems hardly worth while.

Recently, one of us (T. G. B.) published in *Surgery, Gynecology and Obstetrics*, February, 1956, an improved method whereby all the blood from the inferior vena cava is shunted by means of a homologous graft into the left auricle and all the blood from the right lung is directed into the right auricle. Seven patients have been operated upon by this method, and five have been remarkably improved. Among the successes was one child 6 weeks old and another 3 months old.

The Noncyanotic Group

Patent Ductus Arteriosus

It has been our good fortune in 347 operations for patent ductus arteriosus to have no mortality. The ages of these patients varied from a few weeks to 16 years. Included in the group are 9 infants below 1 year of age and 45 infants from 1 to 2 years of age. A number of the infants in heart failure at the time of operation grasped their slim chance of survival and made excellent recoveries. A few patients in the older age group had severe degrees of pulmonary hypertension with bidirectional flow through the ductus. At operation if the pressure in the pulmonary artery fell even slightly when the ductus was occluded division and suture was done. In this age group we have encountered no child whose pulmonary tension increased when the ductus was occluded. In the early days of ductus surgery 21 were ligated. The balance, 326, with 1 exception, have been divided. During all ductus operations the temperature is kept as near normal as possible. From many standpoints, operative closure of a patent ductus arteriosus is the most satisfactory operation in the entire field of surgery for congenital heart disease.

Coarctation of the Aorta

Two deaths occurred in this group, and each is of some significance. The first occurred in a 15-month-old child with all the findings of coarctation of the aorta—and marked enlargement of the heart. During operation while the anastomosis was being done the heart became increasingly slow and stopped. At postmortem examination extensive unsuspected fibroelastosis was found as the cause of death. We have since learned that coarctation of the aorta discovered during infancy is rarely associated with cardiac enlargement. For example, a 9-month-old perfectly well infant seen in 1949, with typical adult type of coarctation of the aorta, had a systolic blood pressure in both arms of 220 mm. of mercury and no cardiac enlargement. This child was observed periodically for six years. The systolic blood pressure varied from 180 to 220 mm. of mercury. At age 6½ years, when the coarctation was successfully resected, there still was minimal enlargement of the heart, although the opening in the strictured aorta would admit only the finest probe.

The second death occurred in a boy, age 13, whose coarctation was complicated by a huge patent ductus which supplied the major portion of the blood flow to the lower segment of the aorta. The ductus was divided, a rather long coarcted segment of aorta was resected, and the proximal end of a large subclavian artery was sutured to the distal end of the aorta. Presumably, the change in hemodynamics resulting from closure of the ductus caused right heart failure shortly after completion of the operation.

Resection of the adult type of uncomplicated coarctation in 50 patients of ages from 6 to 16 years was attended by no mortality.

Anomalies of the Aortic Arch

Six deaths occurred in this unusual group of twenty-five anomalies of the aortic arch. Two of these deaths were preventable. The first child was operated upon in 1947. At operation the entire aortic arch and its branches appeared normal. Four days after operation the child had an attack of dyspnea similar to those occurring before operation and died. At postmortem examination a small persistent posterior arch was found—a condition not described in medical literature to that time. Division of this small offending vessel would have been so simple.

A second death occurred in a child who had a right aortic arch with a large anomalous vessel which coursed around the right side of the trachea, behind the esophagus, and attached itself as a ductus arteriosus to the pulmonary artery at the left of the trachea. The anomalous vessel was ligated and divided. The ligature slipped off the end of the vessel behind the esophagus. Hemorrhage was fierce and fatal.

Two infants with severe stridor and dyspnea presented difficult anesthesia problems. Pressure on the trachea by the anomalous vessel was so great that it was impossible to get an adequate airway beyond the constriction. Operation seemed imperative and was carried on, although much of the time the infant was cyanotic. In the first case operation was interrupted seven times to expand the lungs and, temporarily, to improve oxygenation. The child died on the operating table of anoxia. In the other case, similar in all details, death due to anoxia occurred two hours after operation.

Two infants developed postoperative edema of the trachea due to forceful intubation and required tracheotomies. Both died weeks later of complications of the tracheotomies. Granulation tissue piled up at the point where the end of the tracheotomy tube irritated the mucus membrane and caused sudden suffocation. The anesthesiologist (W. O. McQ.) insists that responsibility for four of these deaths is his because of technical errors and poor choice of endotracheal tubes. The surgeons have confessed their errors. All are agreed that anesthesia for infants with tight vascular rings is a real problem.

Interatrial Septal Defect

In this category only five defects had been closed up to February, 1955. All were repaired by suture without opening the right auricle except to insert a finger as a guide to the needle. The child who died had a rather large defect closed by the Sondergaard, or single suture, technique. Death 24 hours after operation was due to sudden imbalance of circulation as manifested by increasing and eventually fatal pulmonary edema. The closed method of suture is still being used—wisely or unwisely, we do not know.

Miscellaneous

In the group of nine miscellaneous cases, there were five in which the preoperative diagnosis was wrong or an improper procedure was done, or both. Aortic-pulmonary anastomoses were performed upon five children with a preoperative diagnosis of tricuspid atresia in one and tetralogy of Fallot in four. At postmortem examination the child who was diagnosed as having tricuspid atresia was found to have tricuspid stenosis and an interatrial septal defect. Death was due to atelectasis and bronchitis. The postmortem diagnoses in the other four were as follows: Ebstein's disease, transposition of the great vessels with pulmonary stenosis, congenital mitral atresia and interatrial septal defect, and anomalous venous return of much of the blood by way of the portal vein.

Four children with uncertain diagnoses died after exploration and at postmortem examination were found to have rhabdomyoma, fibroelastosis, infantile coarctation

with associated intracardiac anomalies, and truncus arteriosus communis, respectively.

Comment

Anesthesia.—We are well aware that the abnormal physiological state of anesthesia, although not listed as a cause of death, is often a contributing factor. Traumatic intubation, laryngospasm, periods of hypoxia or hypercarbia, hypotension or hypertension, and other infractions of basic rules may be relatively harmless in the good-risk patient but tip the scale toward a fatal outcome in the poor-risk patient. This statement is supported by the fact that in 347 operations for closure of a patent ductus no deaths occurred, whereas in a similar number of patients with pulmonary stenosis there were many deaths. Personnel and technique of anesthesia were the same in both groups.

Asphyxia was the greatest problem and in the majority of instances was unavoidable. If, during operation while one lung is collapsed, sufficient blood does not flow to the other lung to provide adequate oxygenation, the anesthesiologist and surgeon are helpless. Slowly increasing bradycardia and a weak, almost imperceptible pulse are manifestations of cardiac fatigue. The heart is a demanding organ, requiring a constant supply of food, and so long as it gets an adequate supply it will continue its sole function of beating.

Reexpansion of the lung during operation will often be followed by dramatic improvement in cardiac action. However, after the vessels have been clamped preparatory to anastomosis there is no turning back. During this period of unavoidable oxygen deprivation patients die of hypoxia.

The technique of anesthesia and anesthetic agents used have remained the same throughout this entire series. Cyclopropane has been and still is our choice of agent and is administered by the to-and-fro absorption technique with controlled respiration. It has been said that controlled respiration is harmful. We have not found it so. What is more, controlled respiration immobilizes the chest and mediastinum and makes intrathoracic surgery much easier.

The popular belief that cyclopropane causes cardiac irregularities has not been substantiated clinically. Continuous electrocardiographic studies on 50 consecutive patients during cyclopropane anesthesia in 1951 (unpublished data) confirmed our clinical observations.

Lowering of body temperature has been routine during operation on cyanotic children since 1948. Very deeply cyanotic children and especially those with transposition of the great vessels are cooled to 85 to 90 F. The moderately cyanotic are cooled to 90 to 95 F, and the mildly cyanotic, good-risk patients are maintained at temperatures near or slightly below normal.

Anesthesia and surgery are irrevocably united and with mutual trust and understanding work hand in hand to achieve the best for the unconscious patient. The surgeon wants safe, smooth anesthesia which will allow him to work with undivided attention. He wants an anesthesiologist who knows from moment to moment the exact condition of the patient and is capable of solving intelligently any problems of respiration and circulation that may arise. The anesthesiologist wants a surgeon to do what he sets out to do with neatness and dispatch. He would like the surgeon to be conscious of time, to respect living tissue, and to maintain a bloodless field. Quick cooperation in temporarily stopping or terminating an operation will lessen the number of deaths laid at the anesthesiologist's door.

Cardiac Arrest.—Although this paper deals with operative and postoperative deaths, we are about to discuss a cause of death which occurred but once, and that time questionably, in this group of 1000 operations for congenital heart disease, viz., cardiac arrest. The term, cardiac arrest, is employed broadly—too broadly—to cover many catastrophes in the operating room. We have long urged that cardiac arrest be

used as a label only for those patients whose hearts, normal, or largely free from disease, suddenly and unexpectedly stop during operation.

Seventeen of the ninety deaths in this group occurred on the operating table. The patients' hearts stopped beating, but for definite reasons. The majority were cyanotic; some had only an exploratory operation; others had shunt operations but were so hypoxic during the procedure that their oxygen-starved hearts became slower and weaker and finally stopped. Two infants with unsuspected fibroelastosis died during operation. Their hearts just stopped beating because they were hopelessly damaged. Three children had brain hemorrhage during operation, and when impulses from the brain were shut off the heart action ceased.

During open chest operations, when the heart is constantly in view, it is possible to see the impending failure of heart action. Often we knew that the heart was going to stop but were powerless because of the basic disease to do much about it. Stopping the operation and inflating the lungs temporarily improved oxygenation and heart action, but as soon as the lung was again collapsed the inevitable became obvious.

Perhaps it is quibbling with terms, but when hypoxia becomes severe enough any heart will stop. Why call that cardiac arrest? If a diagnosis of cardiac arrest in the operating room were made only in case of sudden and unexpected cessation of action of a normal or near-normal heart, the spotlight of study could be focused upon an entity. So long as any death in the operating room is conveniently labelled cardiac arrest, the real villain is apt to escape detection.

The normal or not too damaged heart stops during operation because it receives insufficient food or because it is poisoned. If sufficient oxygen is pumped into the lungs, if carbon dioxide is removed, if anesthetic agents and drugs are used sparingly and with discretion, if blood lost is assiduously replaced, if the anesthesiologist is constantly aware of the moment-by-moment condition of the patient—then cardiac arrest will become exceedingly rare during any reasonable operation.

It would seem appropriate to direct about 95% of teaching and vigilance toward prevention and about 5% toward treatment with machines and massage.

Summary

This report deals with operative and hospital deaths which occurred in 1000 operations for congenital heart disease.

In the group with cyanosis due to pulmonary stenosis remedial by surgery, the mortality year after year has remained near 9%. In the noncyanotic group the mortality has varied from zero in operations for patent ductus arteriosus to 24% in patients with constricting vascular rings.

The causes of death cover a wide range of those due to human frailties, such as oversights, poor judgment, and inexperience, and those due to irremediable pathology.

DISCUSSION

ON PAPERS BY DRS. KENT, FISHER, FORD, AND NEVILLE AND POTTS, MCQUISTON, AND BAFFES

DR. J. W. KIRKLIN, Rochester, Minn.: I am certain that all of us have been impressed with the care with which these patients have been studied and with the accuracy with which Dr. Neville and his associates have analyzed their data.

I suppose the usual role of a discusser is to find some criticism in the paper he is to discuss; unfortunately, I could find nothing in Dr. Neville's paper to criticize, so I will have to limit myself to emphasizing a few of the points he made.

First, we too are convinced of the safety and value of left heart catheterization, as described by Dr. Fisher, Dr. Neville, and their associates. Actually, in this institution we were taught left heart catheterization by Dr. Don Fisher, who was good enough to come from Pittsburgh to teach the men in our laboratory the method of carrying out this procedure. It is done in our hands by a modification of the method that has worked out so successfully by the people who presented the paper.

We certainly have found, in a much more limited experience than theirs, that the procedure is safe

and has given us information of extreme value.

Secondly, I will certainly agree completely with the essayists that more and more precision in preoperative diagnosis should be our goal, rather than less and less precision. It is easy to become enthused about the future of cardiovascular surgery and the wonders of everything that can be accomplished, but I am certain that in our enthusiasm we must not be carried away into thinking that we can treat anything that comes along.

I think that the farther we go the more we are impressed with the necessity of absolutely precise preoperative diagnosis, and left heart catheterization certainly is a great step forward in this direction.

Finally, I would like to emphasize the point Dr. Neville stressed, namely, that in the presence of mitral insufficiency it is difficult on occasion to interpret the gradient between left atrium and left ventricle. A gradient, of course, not only reflects the size of the orifice in question but reflects the flow of blood through the orifice as well.

In the presence of severe mitral insufficiency the flow across the mitral valve is not only the cardiac output but is also the blood which regurgitates into the left atrium and then again passes into the left ventricle.

Our experience has been that in the presence of severe mitral insufficiency the interpretation of the gradient across the mitral valve is fraught with some difficulty.

DR. STUART C. CULLEN, Iowa City: One can find little room for debate on the material presented by Drs. Potts, McQuiston, and Baffes. There are, however, two items of significance that deserve emphasis.

One of these is the method of anesthesia used in these patients. The literature is replete with articles "making a pitch" for a particular agent or technique for a particular operation. The arguments in support of special approaches to an anesthetic problem range from unadulterated speculation to hypotheses based upon fairly well-controlled clinical investigation.

The material just now presented may seem to support such a special or limited solution to the problem of these patients. However, as was pointed out, the successful results are a function of excellent teamwork, alertness to minute changes in the patient, and a willingness to constantly reevaluate experiences and adjust to new information.

The successful use of cyclopropane in these patients emphasizes that the anesthetic agent is of considerably less importance than the anesthetist. So, also, is a surgical technique of secondary importance to the surgeon.

The second item deserving comment is cardiac arrest. I am in utmost sympathy with the attitude expressed. The term "cardiac arrest" is in the same category as "idiopathic epilepsy." In neither term does one have a diagnosis. If a heart fails, a search for such things as hypoxia, overload, anesthetic overdose, and so on, should be made.

The term "cardiac arrest" has come to be a convenient alibi. In some areas it is expected as a part of anesthesia and surgery and is often dismissed without further inquiry.

Unfortunately, the attitudinal set associated with the application of this "diagnosis" discourages investigation into possible causes. Unfortunately, also, from a purely chauvinistic or selfish point of view, anesthesia is the primary suspect when the label, "cardiac arrest," is applied. In contradistinction to our accepted legal standards, anesthesia is guilty until proved innocent.

Why does not the patient who dies suddenly on the street, and in whom there is no demonstrable cause on pathologic examination, suffer from cardiac arrest? Is this a disorder or a label peculiar to anesthesia and surgery?

With the authors of the paper, I make a plea for a diagnosis and not simply a label in those circumstances in which there is failure of cardiac function during anesthesia and surgery.

DR. WILLIS J. POTTS, Chicago: Just one philosophical thought at the close of today's meeting. Death following operation is distressing because of its cruel finality. Those little crosses on the hillside stand out so vividly and so permanently.

In this group of 90 deaths there were 89 postmortem examinations. When the spotlight of postmortem examination is focused upon the cause of death, the reflection inevitably promotes bona fide humility.

Argentaffin Carcinomas

Report of Twenty-Nine Cases, Six Malignant

W. JAMES ELDRED, M.D., Oakland, Calif.

The argentaffin tumor of the gastrointestinal tract is no longer a medical curiosity. It has been recognized since 1888 that this tumor has malignant propensities. Indeed, such tumors occurring in the small bowel and appendix (in which locations they are commonest) were classified with the carcinomas (adenocarcinomas), and for many years it was difficult to single out, in a series of epithelial tumors, which ones were adenocarcinoma and which were the more benign argentaffin carcinoma.

However, they became recognized as a distinct pathological entity around the turn of the century, and the unfortunate name of "carcinoid" was applied. The reason for the consideration of these tumors as distinct from carcinoma was that the appendiceal tumors showed, in general, a benign course. But "carcinoid" of the appendix does metastasize; in 1926, Stewart and Taylor reported such a case and collected eight other cases of appendiceal argentaffinoma with metastases.[1] Their case occurred in a 31-year-old woman and presented as an appendiceal tumor with large pelvic metastatic deposits. Interestingly, after excision of all the grossly visible tumor, the patient did well, and she was alive 11 years later. In addition to the frequent lack of metastases in the appendiceal "carcinoids," the histology of the tumor lacks some of the usual criteria of malignancy, viz., pleomorphism of nuclear structure and frequent mitoses.

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In contradistinction to the argentaffin tumor of the appendix, those of the small bowel (and the rarely occurring tumor of the rectum) are well recognized by surgeons and pathologists to be capable of malignant behavior. Argentaffin tumors comprise 8.3% of all small intestinal tumors and 20% of all malignant tumors of small intestine. This was emphasized by Carr in 1931, in a report of two cases in the small bowel, both of which caused symptoms and were operated upon and one of which had metastasized to regional lymph nodes.[2] Ariel reported eleven cases of small bowel argentaffinoma in 1939, five of which were malignant.[3] He reviewed 237 cases from the literature, 25% of which had metastasized. He pointed out that the prognosis is, generally speaking, good but that the tumors can cause death. Of the extra-appendiceal lesions in Grimes and Bell's series of gastrointestinal tract carcinoids, 100% were malignant; all eight of them were in the small bowel.[4] Foreman reported 38 carcinoids, 14 of which were in the small intestine.[5] Four of the fourteen were malignant. Grimes and Bell cite Dockerty's series of 30 cases occurring in the small bowel, 13 of which were malignant. In the present series, which includes 15 small bowel argentaffin carcinomas, 5 were malignant. Spread to regional nodes is frequent, and spread to more remote locations occurs occasionally (liver, lungs, kidneys, adrenals, retroperitoneum, bone, subcutaneous tissue, brain, and pancreas). The percentage of malignancy of small bowel argentaffinomas varies considerably, depending on the particular report.

Because of the undoubted malignant potential of these tumors, which are epithelial neoplasms capable of invasion and metastasis, the term argentaffin carcinoma or argentaffinoma should probably be used.

"Carcinoid" is well entrenched in the literature, but it is misleading, often giving an erroneous concept of how these lesions should be treated. Willis advocates the term argentaffin carcinoma and suggests the name Kultschitzky-cell carcinoma, for there is good evidence that the tumor arises from the specialized granular epithelial cells of the crypts of Lieberkühn, the yellow cells of Kultschitzky.[6] Masson showed these cells to have selective ability to reduce ammoniacal silver nitrate, the argentaffin reaction. The cut surface of the tumor, and its metastases, show the characteristic yellow-orange color, like the cells from which they arise.

Pathology

Argentaffin carcinomas of the small intestine occur about as frequently as the adenocarcinomas. The gross appearance of the tumor is usually a discrete, nodular mass, sometimes polypoid, with a rubbery consistency and showing on section a yellow hue, as mentioned above. The ileum is more often affected than the jejunum. Young growths often take the form of nodules projecting into the bowel lumen, covered by intact mucosa, but ulceration may occur. Older tumors may encircle the bowel, causing stenosis. Even in the well-defined tumors, fine extensions are seen on microscopic study to grow into the muscularis and serous coats; hyperplasia of the invaded muscular tissues and increased fibrosis occur with this infiltration.

The microscopic appearance is that of well-defined clumps or strands of small closely packed polyhedral cells, with here and there small glandular lumina or distinct glandular acini. The nuclei are round, distinct, and regular, with punctate, sometimes coarse, chromatin granules and little evidence of pleomorphism or excessive mitoses. The cytoplasm is faintly eosinophilic, with poorly defined cell borders. The more actively growing tumors show varying degrees of anaplasia, in part or whole, but there is seldom any difficulty in recognizing the familiar pattern, in primary or in metastatic deposit.

Whatever the carcinogenic factors may be, they operate over the whole mucosa of the small bowel, for the tumors are frequently multiple; sometimes as many as 20 or 40 visible tumors occur. They have been seen where argentaffin cells have been described, including stomach, pancreas, gall bladder, and Meckel's diverticulum, as well as small and large bowel. These cells are particularly frequent in the appendix, but they have been described in other parts of the colon (including the rectum). Argentaffin carcinoma of the large intestine, excluding the appendix, is rare. Peritoneal spread is accompanied by fibrotic contraction and kinking of the intestine. This, in turn, may lead to intestinal obstruction, which is frequently the presenting symptom. Ninety per cent of malignant tumors of the appendix are argentaffin carcinomas. They are usually situated at or near the tip, as a firm nodule of yellowish tissue, 1 or 2 cm. in diameter. It may be well defined or may diffusely infiltrate the coats of the appendix. Most are discovered incidentally at postmortem examination, or in appendices surgically removed for appendicitis. The appendiceal tumors are usually single, discovered at ages ranging from 12 to 70 years, the average in most series being about 30 years. The sexes are nearly equally affected, but some series report predominance of females; (this is probably due to the more frequent removal of appendices in that sex, incident to elective pelvic surgery). Metastases have been reported from these appendiceal tumors, to the peritoneum, lymph nodes, liver, and elswhere, but most cases are cured with removal of the appendix.

Material

The 29 argentaffin carcinomas herein reported were collected from the postmortem records and surgical pathology files of San Francisco Hospital (University of California Service) and Franklin Hospital in San Francisco, representing the 23-year period from 1932 to 1954. Of these 29 cases, 24 are analyzed (5 records were unavailable). Seventeen of the twenty-nine were

treated; treatment was surgical. (One had surgery plus mechlorethamine [nitrogen mustard] therapy, and one had surgery plus x-ray therapy.) The remaining 12 were found at autopsy.

Argentaffinomas make up 0.23% of the 6092 autopsies in this series. This figure is close to that given in most large autopsy series. The most frequent site of argentaffin carcinomas is the appendix; the ileum is the next most frequent. Most authors report a higher incidence in the appendix than elsewhere, but the present series of 29 argentaffinomas includes 10 appendiceal tumours. (The reason for this may be that the appendiceal tumors are often very small and may be overlooked at the time of pathological examination unless several sections of the viscus are taken, including a longitudinal section through the tip.) The rest of the gastrointestinal tract is represented as follows: ileum, 9 cases; small bowel (unspecified), 3; rectum, 3; jejunum, 2; duodenum, 1; cecum, 1. The appendiceal argentaffinoma is frequently found in an appendix removed for inflammation, as noted above. Three of the present series of ten appendices were so inflamed. In Grimes and Bell's report of 11 carcinoids of the appendix, 4 were inflamed.[4] It is for this reason that the appendiceal argentaffin carcinomas have such a good prognosis; i.e., the tumor is often obstructing, and obstruction in a blind tube (appendix) gives rise to symptoms. Thus, early surgery results in removal of the tumor and there is less liklihood for the tumor to have progressed to the stage of serosal and lymph node spread than in the identical tumor situated elsewhere in the gastrointestinal tract. It is probably because of this that the age incidence of argentaffinoma is quite different in the various anatomical locations of the tumor. In the small bowel argentaffin carcinoma may grow for years before producing symptoms of obstruction or other symptoms referable to metastases. Many of the small nodular tumors of the small bowel are discovered incidentally at postmortem examination. Although the average age at which the appendiceal tumors are discovered is about 30 years, it is 42 years in my series. On the other hand, argentaffinomas of the small intestine most frequently affect the middle- and older-age groups, around 58 to 60 years, and this was so in the present series (average, 58.7 years).

Of the surgical cases, nine were appendectomies (including one incidental appendectomy done at the time of pelvic surgery), five were operations for bowel obstruction

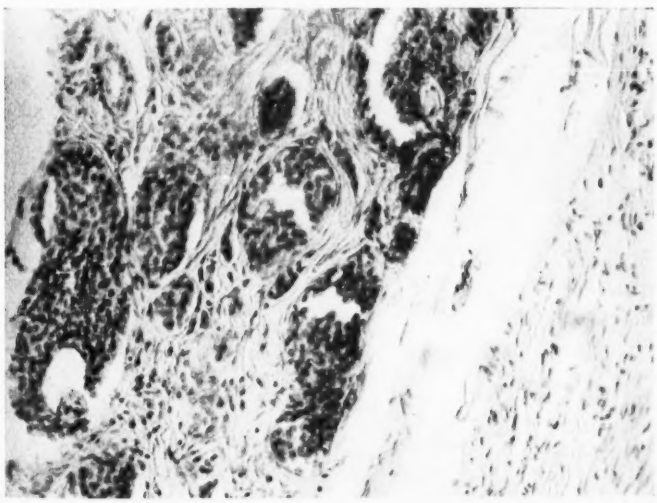

Fig. 1.—Argentaffinoma infiltrating the submucosa and muscularis of the appendix. Note the pseudoacini.

(including one nonmetastasizing argentaffinoma of the jejunum, causing intussusception), and two were local excision of rectal tumors. Appendectomy apparently cures the cases of argentaffin carcinoma occurring in the appendix, but if the tumor is recognized or suspected at surgery a wide excision of the mesoappendix should be done, as the neoplastic cells frequently invade all coats of the viscus and extend to the mesentery.

However, some surgeons feel that if the diagnosis of argentaffinoma of the appendix can be made at operation, even though the tumor shows no gross evidence of spread beyond the serosa, radical surgery should be done. Anlyan advocates right colectomy and ileotransverse colostomy, with eradication of the lymph nodes draining the area.*

Of interest is the fact that one of the cases of ileal argentaffinoma (Case 1) with lymph node (and probably hepatic) metastases did not have symptoms but had a small mass on the ileal serosa, which was locally excised at the time of hysterectomy. She has no symptoms one year later, and a gastrointestinal x-ray shows no abnormality of terminal ileum. An exploratory laparotomy is planned for her in the near future.

* Anlyan, A. J.: Personal communication to the author.

Case Histories of the Six Malignant Argentaffinomas

CASE 1.—*Argentaffinoma of ileum with metastasis to the mesentery and liver*

A 44-year-old white spinster entered for removal of large lower abdominal tumor diagnosed preoperatively as leiomyoma uteri. No history of abdominal pain or change in bowel habit. Examination showed nothing remarkable except a large (12 cm. diameter) suprapubic mass. At surgery a large leiomyomatous uterus was removed. In the ileum, 30 in. from the ileocecal valve, on the antimesenteric border, was a 2 mm. gray firm mass, directly opposite some hard yellow-gray lymph nodes measuring 1 cm. in diameter. A firm rubbery 1 cm. nodule also was palpated in the left lobe of the liver. The mass was excised locally from the ileum; the mesentery was not excised. Pathological examination of the small mass showed a crisp-cutting, cream-colored lesion, which on microscopic examination showed nests of small spherical tumor cells, invading the muscularis of the ileum. The cells had the fine chromatin and lack of both pleomorphism and mitotic activity characteristic of carcinoid tumor. This patient has been well for the past year; there are no physical findings, and a recent gastrointestinal x-ray shows no abnormalities of the terminal ileum.

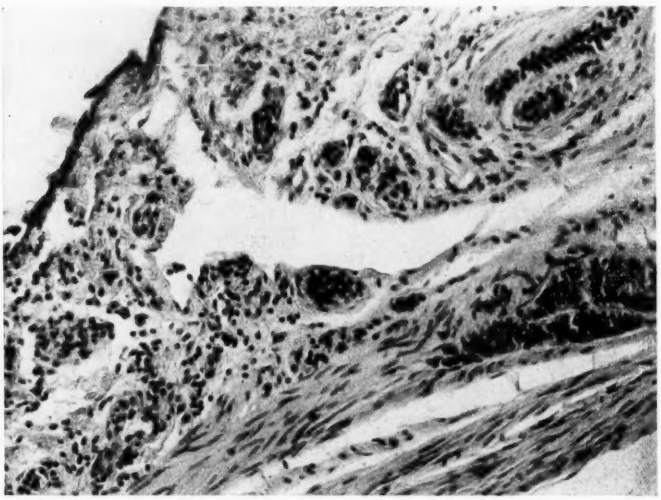

Fig. 2 (Case 1).—Argentaffinoma in the muscularis and penetrating to the serosa of the ileum.

CASE 2.—*Argentaffin carcinoma in Meckel's diverticulum with metastases to the liver*

A 50-year-old woman entered hospital with a six-month history of diarrhea, weight loss, and abdominal fullness. Examination showed a large nodular liver, pitting edema of both lower extremities, a harsh apical systolic murmur, and eleva-

tion of the diaphragms due to the large liver. Blood cell count was normal, but the icteric index was slightly elevated (17.2). Barium enema showed an area of constriction in sigmoid, which was never adequately explained, for at surgery the findings were a liver massively infiltrated with metastatic tumor, and Meckel's diverticulum containing a polypoid tumor at its tip. The latter was excised, and a biopsy specimen was taken from the liver. Pathological report showed the diverticulum to contain small nests of neoplastic cells in mucosa and submucosa occurring in cords and clumps. The nuclei had granular chromatin and little pleomorphism. The same histopathology occurred in the liver nodule. Diagnosis: carcinoid in Meckel's diverticulum, with hepatic metastases. Patient has been given several courses of mechlorethamine intravenously, with some regression in size of the abdominal mass.

CASE 3.—*Argentaffin carcinoma of cecum with metastasis to the mesentery and liver*

A 58-year-old man was hospitalized with a two-month history of abdominal fullness and pain in the right side of abdomen as well as a 20 lb. weight loss. X-rays showed obstructing lesion of the right colon. Examination demonstrated a thin, wasted man, with a right lower quadrant mass 6×2×3 in., firm and fixed. Nodules were felt

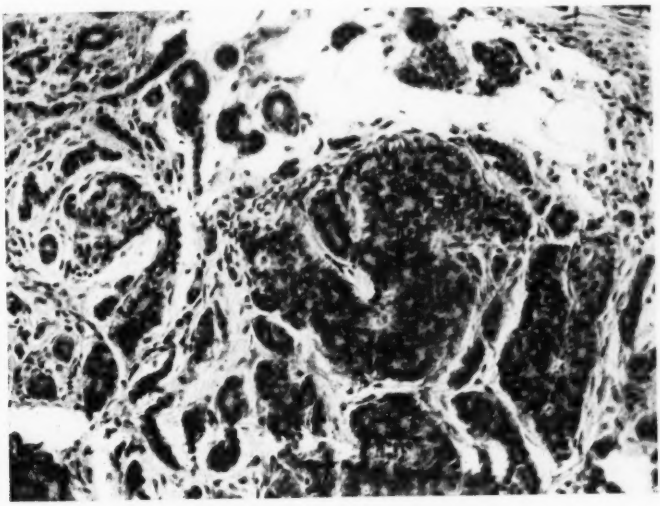

Fig. 3 (Case 3).—Argentaffin carcinoma of cecum.

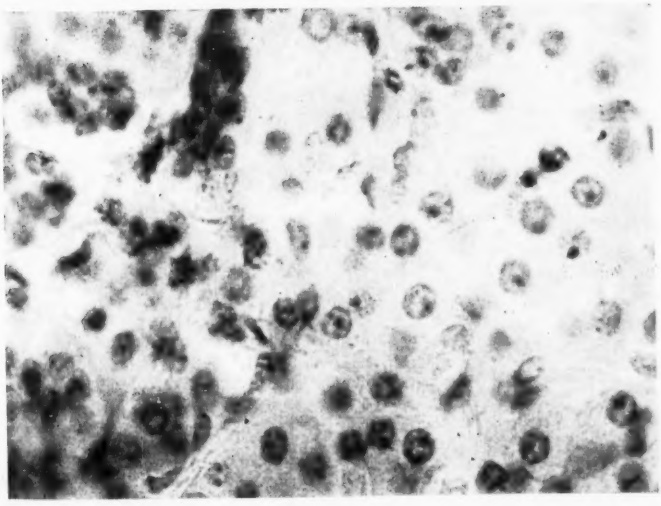

Fig. 4 (Case 2).—Argentaffin carcinoma metastatic to liver; the tumor cells are on the left of the field.

in the cul-de-sac. The hemoglobin was 11.5 gm. per 100 cc., and the white blood cell count was 4400, with 83% polymorphonuclear cells. At surgery a large (15 cm. diameter) malignant mass replaced the cecum, with complete obstruction of terminal ileum. There were widespread peritoneal metastases and liver nodules. Ileotransverse colostomy was done, and the mass was biopsied. Pathological report was three large lymph nodes replaced with sheets of small hyperchromatic spherical cells with regular nuclei and scant cytoplasm. Pseudoacinar formation was present, and there were rare mitoses. Diagnosis: carcinoid. Patient reentered hospital four years later with bowel obstruction. He was reoperated upon, and omental adhesions were released. It was noted that there had been little change in the appearance of the tumor from four years previously. He died seven months later; there was no autopsy.

CASE 4.—*Argentaffin carcinoma of ileum with metastases to mesentery and peritoneum*

A 50-year-old white woman was sent to hospital with a six-month history of mass in right lower quadrant and intermittent morning vomiting. Pelvic examination showed a large cystic mass high in right fornix, and a nodular mass 2×3×3 cm. in rectovaginal septum. Gastrointestinal series was negative. At surgery a large tumor mass occurred between leaves of the mesentery of ileum and a nodule was seen in the omentum, which was biopsied. Other peritoneal implants were present. She received 20 deep x-ray treatments but returned to hospital with intestinal obstruction a month later. She was treated conservatively and soon died. Postmortem examination again showed the mass in the mesentery, with constricted loops of small bowel adherent and kinked about the mass. Tumor was present in the submucosa and mucosa of ileum, causing a sharp kink near the cecum. Microscopic examination of the tissue demonstrated fairly uniform polygonal cells, with light round nuclei, containing heavy chromatin but little pleomorphism. The masses of cells were supported by dense fibrous stroma and invaded all layers of bowel. The same tissue was found in the nodules removed from behind the left fornix and in several lymph nodes.

CASE 5.—*Argentaffin carcinoma of ileum with metastases to peritoneum, mesentery, para-aortic and mediastinal lymph nodes, lung, liver, marrow*

A 65-year-old white man entered with a four-month history of diarrhea, emesis, and abdominal enlargement. Examination showed an obese man, breathing heavily, with signs of fluid in the right chest. A loud harsh precordial murmur was heard, and there were frequent ectopic heartbeats. The abdomen was markedly distended, with fluid wave, and a right upper quadrant mass that was thought to be enlarged liver. Edema of genitalia and the lower extremities was noted. The electrocardiogram showed a complete heart block, and the white blood cell count was slightly elevated. Paracentesis abdomini released 9000 cc. of cloudy white fluid, which had no cells in the centrifuged "button." Gastrointestinal x-ray showed bizarre pattern of small bowel. He was treated for congestive heart failure but died six days after admission. Necropsy showed numerous small white nodules sprinkled over the small bowel, from 0.5 to 1.0 cm. in diameter, with cicatrization of the mesentery. The lymph nodes along the aorta and spine were enlarged, matted, and hard. Liver was studded with white metastatic nodules. The mediastinal nodes were greatly enlarged as well. The small bowel was moderately dilated and edematous. Three feet proximal to the ileocecal valve there was a tumor on the antimesenteric border of the ileum, 15×20 cm., with scarring and contraction of bowel wall about this, producing partial obstruction. The mesentery likewise showed scarring, with many involved nodes. Microscopic study of the constricting lesion showed a small ulcerating surface interrupting the mucosa and nests of small uniform cells invading all coats of bowel. The cells were typical of carcinoid. The same tumor process was seen in the adventitia around the aorta, in the retroperitoneal lymph nodes, bronchial nodes, marrow, liver, and lung.

CASE 6.—*Argentaffin carcinoma of ileum with metastases to cecum, mesentery, liver, and ovaries.*

A 68-year-old white woman was sent to hospital with a one month history of abdominal pain, distention, vomiting, and diarrhea, together with considerable weight loss. Examination showed an elderly obese woman, dehydrated, with a rapid pulse (110). Respirations were 24 per minute. The abdomen was distended and tympanitic. Bowel sounds were high-pitched, and distended loops of bowel were palpable in the left quadrants. X-rays confirmed clinical impression of bowel obstruction, the barium enema demonstrating a cecal defect and shortening of the colon. Exploratory laparotomy showed a large malignant mass apparently arising from the ileum, involving cecum and the mesenteric nodes as well as the liver. A short-circuiting operation was done, but she had a short postoperative course and died of peritonitis a few days later. The postmortem examination showed the same gross picture, except that the mesentery was nodular and woody hard. Sections of the terminal ileum showed the submucosa to be 1 cm. thick, with hard gray tumor tissue infiltrating it for a distance of several centimeters. The microscopic examination showed sheets of tumor cells having the histologic pattern typical of carcinoid. There were similar nests of carcinoid cells in the cecum, mesenteric nodes, liver, and ovaries.

Clinical Considerations and Treatment

Symptoms of small bowel obstruction, together with x-ray evidence of a filling defect or kinking in the terminal ileum, in a middle-aged person should make one suspect argentaffinoma. This was recognized by Carr; i. e., signs and symptoms of intestinal obstruction, together with x-ray evidence suggesting tumor in the terminal ileum, were present in his cases.[2] Porter and Whelan reported a case of a 37-year-old man with intermittent bowel obstruction, pain, weight loss, and diarrhea.[7] In addition, he had a right lower quadrant mass; he was operated upon, and an argentaffinoma of terminal ileum with mesenteric lymph node metastases was widely resected. He was well 10 years later. This patient had a "tetrad" of symptoms stressed since then by Grimes and Bell, viz., intermittent small bowel obstruction, with abdominal pain, diarrhea, and weight loss.[4] These authors feel that this tetrad is characteristic of argentaffinoma. If there is x-ray evidence of kinking or a filling defect of the terminal ileum, the diagnosis is strongly suspected. Five of the six malignant cases summarized in the Table presented with bowel obstruction and more or less of the tetrad of symptoms referred to above.

Recently, another feature of argentaffinomas, which may aid in the preoperative diagnosis, has been stressed by Thorson and co-workers.[8] In 1954 these workers described a new syndrome of carcinoid of the small intestine with metastases to the liver, together with valvular disease of the right side of the heart, sudden flushing of the skin, an unusual type of patchily distributed changing cyanosis, and "asthma." The cause of the syndrome is thought to be an argentaffin carcinoma of the small intestine with hormonal properties and extensive metastases to the liver. Thorson discusses substances with vasoactive properties and points out that serotonin, or enteramine (5-hydroxytryptamine), is the one which in its effects seems most likely to correspond with the signs and symptoms of the syndrome. Recently, it has been extracted in considerable amounts from an argentaffinoma. The findings and symptoms of the syndrome presented in Thorson's series include plethoric coloration and total or partial cyanosis in the absence of polycythemia. Peculiar patchy flushing of the skin occurred in the cases he reported. There were seven such definite cases of this rare syndrome, in two of which the presence of argentaffin carcinoma was suspected before operation because the patients had sudden flushing of the skin and patchily distributed cyanosis. Both of these patients proved at surgery to have malignant argentaffinoma. Thorson cites other authors reporting cases of argentaffinoma associated with this pecul-

Malignant Argentaffin Carcinomas

Case	Sex	Age, Yr.	Bowel Obstruct.	Primary Tumor	Metastases	Comment
1	F	44	No	Terminal ileum	Mesentery, liver	Discovered incidentally at hysterectomy; locally excised; well 1 yr. later
2	F	50	Yes	Meckel's diverticulum	Liver	Presented with picture of widespread metastases alive 2 yrs. later; receiving mechlorethamine
3	M	58	Yes	Cecum	Mesentery, liver	Surgery for bowel obstruction; died 4½ yr. later no change in appearance of tumor
4	F	50	Yes	Ileum	Mesentery, peritoneum	Surgery for bowel obstruction; large mass in leaves of mesentery; biopsy only; x-ray therapy; died of recurrent obstruction a month later
5	M	65	Yes	Ileum	Peritoneum, mesentery, periaortic & mediastinal nodes, lung, liver, marrow	Died of metastatic disease, including ascites and bowel obstruction; no operation
6	F	68	Yes	Ileum	Cecum, mesentery, liver, ovaries	Surgery done for bowel obstruction; died of peritonitis in a few days

iar type of vascular phenomenon. At the University of California Hospital, recently, Torrey studied two other patients with this type of vasomotor disturbance and skin changes who proved to have, at operation, malignant argentaffinoma.† Bean and coworkers report two patients with pathologic findings of carcinoid of the small intestine with hepatic metastasis, unusual lesions of the tricuspid and pulmonic valves, and telangiectasia with a proliferative and thrombotic disorganization of blood vessels of the skin, together with transient flushing, mottled cyanosis, diarrhea, asthma, and signs of valvular lesions of the right heart, with edema and congestive failure. They explain the combination of symptoms and findings on a humoral basis, that the carcinoid, with its metastatic deposits, manufactures serotonin and releases it into the inferior vena cava erratically and that this produces a turmoil in valves and endocardium of the right heart and the phenomenon of brisk flushing. The authors suggest that a molecular antagonist to serotonin should be tested as a possible agent of palliation or cure.[9]

The radical surgical extirpation of such tumors is often followed by a relatively long and comfortable life. Removing the primary tumor in cases with extensive metastases often results in arrest of further metastases for several years, unlike the results in cases of adenocarcinoma. In Case 3, irremovable local and hepatic metastases were present at the time of the first operation. Ileotransverse colostomy was done. The patient lived four more years and died of bowel obstruction. There was little or no change in appearance of the tumor at the time of the second operation, done for relief of the obstruction.

Several authors have reported similar cases, in which removal of the primary tumor resulted in apparent regression of the metastases and resulted in the patient's living for 5, 10, and even 20 years, without showing any ill effect. In other words, radical surgery is justified in some cases of advanced argentaffin carcinoma, where palliation alone would be the treatment were the lesion an adenocarcinoma.

One of the six malignant cases presented here came to hospital with a four-month history of diarrhea and abdominal enlargement. He was treated for congestive heart failure but died within a week after hospitalization. Postmortem examination showed argentaffin carcinoma of the ileum with widespread peritoneal and distant metastases.

There were three cases of rectal argentaffinoma in this group, none of which had metastasized. Two were removed locally; the third was an incidental finding in the necropsy room. Foreman presented five cases of argentaffinoma occurring in the rectum, of which one was malignant.[5] He summarized (in 1952) all previously reported rectal argentaffinomas, concluding that the malignant variety in the rectum is more rapidly fatal than malignant tumors of the small bowel. He recommends combined abdominoperineal proctosigmoidectomy for certain rectal growths, including the large bulky ones, the annular tumors, the fixed, and the recurrent argentaffin carcinomas in that location.

Duodenal argentaffinomas are very rare. One occurred in this group. There were three reported by Hazard and Wise in 1951, who cite eight others previously reported.[10] Their cases were roentgenologically indistinguishable from benign tumors of the duodenum or prolapsed polypoid gastric lesions. Hazard and Wise favor local excision of all duodenal tumors for pathological study.

Although surgery is the best treatment for the great majority of argentaffin tumors, some may be benefitted by x-ray or mechlorethamine. Ariel's case of locally recurrent argentaffinoma treated by x-ray was apparently cured for two and one-half years.[3] One of the cases in the present series received irradiation for a large tumor in the mesentery of the ileum, which

† Torrey, F.: Personal communication to the author.

was biopsied. However, the patient died in one month, of recurrent bowel obstruction. was thought to be inoperable carcinoma and

An interesting finding was the presence of another malignancy in 3 of the 29 cases of argentaffinoma analyzed here. This has been noted by others, e.g., Hazard and Wise [10] and Foreman.[5] In my series one patient had bronchogenic carcinoma, one had carcinoma of the prostate, and the third had a (successfully treated) carcinoma of the cervix uteri.

Summary

Argentaffin tumors of the gastrointestinal tract are discussed, and 29 cases are presented, 6 of which were malignant.

The use of the term "argentaffin carcinoma" is suggested rather than "carcinoid."

The treatment for this tumor occurring in the appendix is appendectomy with wide excision of the mesoappendix.

Intermittent small bowel obstruction or x-ray demonstrable filling defect or kinking of the terminal ileum, in a middle-aged patient, should alert one to diagnose argentaffin carcinoma.

Reference is made to a new syndrome, which, although rare, should be kept in mind in the evaluation of patients with peripheral vasomotor symptoms; this should result in more cases of argentaffin carcinoma being discovered and brought to operation.

The treatment of argentaffin carcinoma is surgical. Radical excisional surgery, even in the presence of distant metastases, is indicated, because of the favorable prognosis in this disease and the frequent stabilizing of the metastatic deposits when the primary growth is removed.

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Complete Anatomical Correction of the Tetralogy of Fallot Defects

Report of a Successful Surgical Case

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The imaginative Blalock-Taussig anastomotic operation, in the decade since its introduction, has brought effective palliation to the lives of many previously crippled from the physiological abnormalities associated with Fallot's tetralogy. Perhaps even transcending these benefits has been the arousal, by these same dramatic accomplishments, of a serious interest in congenital cardiac malformations among pediatricians, cardiologists, and surgeons. Everlasting credit should be accorded these pioneer workers and Robert Gross for their stimulating discoveries, presentation of bold techniques, and their over-all accomplishments in salvaging lives otherwise prematurely doomed. Through their deeds, for the first time, a widespread interest was keenly felt in the medical profession for the plight of those tens of thousands of infants born each year in the United States with some form of potentially curable congenital heart disease.

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The only logical goal in any individual patient, and hence the one we all seek, is the complete correction of all the existing cardiac defects. After having thus restored the circulation to normal anatomically and physiologically, one can for the first time hope that life expectancy can thereby be lengthened to its full span. In this regard it is pertinent to point out that virtually the entire mortality in corrective surgery is the initial one. On the other hand, inevitably the mortality associated with palliative surgical procedures will continue to rise at an abnormal rate with the passage of time. Few would seriously dispute, therefore, the greater potential merit of curative versus palliative surgery. Hence, this therapeutic goal has been the guide for our research efforts.

The following is the report of a boy, seriously ill with the tetralogy of Fallot defects, in whom complete anatomical restoration has been achieved. This concept is affirmed by his subsequent dramatic clinical improvement as well as by objective roentgenographic and catheterization studies carried out six months postoperatively. The technique of controlled cross circulation was utilized for the total by-pass of the heart and lungs during the necessary interval of open cardiotomy. At that time the patient's ventricular septal defect was closed by the precise placement of silk stitches under direct vision. Next the obstructing infundibular muscle was resected until an adequate outflow channel had been developed.

Report of Case

The patient, a 17-month-old boy, was seen for the first time on Oct. 21, 1954, at the University

Heart Hospital Out-Patient Clinic. Because of the child's grave appearance he was admitted to this hospital the same day (Fig. 1*A*). The physician who had delivered the child had informed the family then that the infant was a "blue baby."

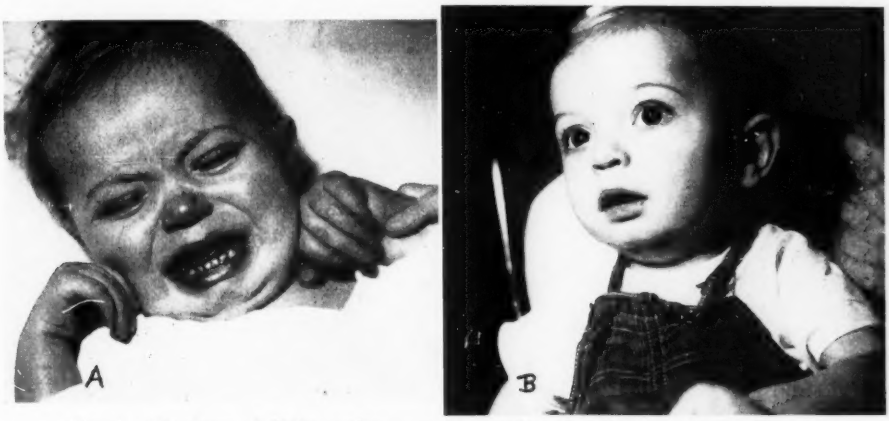

Fig. 1.—Tetralogy of Fallot patient, age 19 months. *A*, prior to surgery. The severe systemic arterial desaturation (25%) is evident in lips, tongue, face, and hands. The patient was unable to sit up alone. *B*, the same patient seen four weeks after closure of his ventricular septal defect and resection of the infundibular pulmonic stenosis. At this time he already had reacquired the ability to sit up unaided. The femoral artery oxygen saturation is 94%, and recatheterization (six months postoperatively) has indicated normal right heart measurements.

The pattern from birth had been one of increasing illness manifested by dyspnea even at rest and progressively more marked cyanosis. The child sat alone for the first time at 9 months of age, but during the three months just preceding hospitalization he was no longer capable of this effort. Also during this latter period the infant not only had failed to gain weight but had lost 1 lb. (454 gm.).

Physical examination at the time of admission disclosed an underdeveloped (8000 gm.) intensely cyanotic irritable infant who was extremely dyspneic. His temperature was 100.6 F. There was a Grade 3 systolic murmur over both apex and base of the heart, and loudest along the sternal border. The pulse rate at rest was 170 per minute. The liver was moderately enlarged. The admission diagnosis based upon these clinical findings was complete transposition of the great vessels. The admission electrocardiogram was abnormal and disclosed evidence of right ventricular hypertrophy and strain, a sinus tachycardia, as well as peaked P waves. The hemoglobin was 12.0 gm. per 100 cc. with a hematocrit value of 50%. The leucocyte count was 14,000 per cubic millimeter with only 9% neutrophiles. Urinalysis, bleeding, clotting, and platelet counts were normal.

The admission roentgenograms showed moderately advanced cardiomegaly due in part to the right ventricular enlargement. The pulmonary vascular markings were decreased and the pulmonary artery segment flattened. (Fig. 2*A*). Four days after admission angiocardiography was carried out by injecting 12.5 cc. of 70% sodium acetrizoate (Urokon) rapidly into the saphenous vein. These films demonstrated opacification of the right atrium, right ventricle, and both the aorta and pulmonary artery. The visualization of the latter was never good, and its small size was interpreted as suggestive of infundibular rather than a valvular type of stenosis, but no actual stenotic site was seen. These angiocardiographic studies ruled out the diagnosis of complete transposition of the great vessels. There was still some uncertainty, however, as to whether the child had a trilogy or tetralogy of Fallot. The cardiologists favored the former because of the cardiomegaly. Cardiac catheterization, done one week after admission, substantiated the diagnosis of tetralogy of Fallot (Table).

This child was then accepted for a curative surgical operation. Because of his desperately ill appearance, even while in an oxygen tent, the maximum medical improvement possible was sought during several weeks of careful preoperative management. He was digitalized on Nov. 2, and in association with this his clinical status was better, despite a further loss in body weight of 1 lb. (454 gm.).

The Operation

On Dec. 3, 1954, corrective surgery was carried out with employment of the technique of controlled

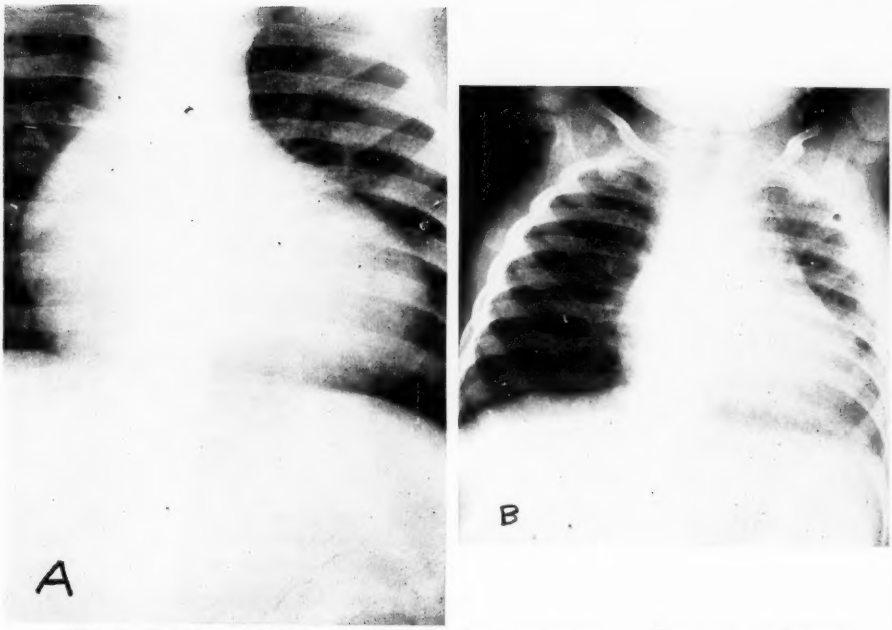

Fig. 2.—Tetralogy of Fallot. *A*, preoperative roentgenogram. The sparse pulmonary vasculature concavity of the pulmonary artery segment and elevated cardiac apex are evident. The cardiomegaly was due to the cardiac decompensation present. *B*, postoperative roentgenogram, at the time of cardiac recatheterization six months after surgery. Note the more normal cardiac silhouette and lung fields. The cardiac transverse diameter has decreased since the corrective surgery was performed.

Correction of Tetralogy of Fallot Defects by Closure of the Ventricular Septal Defect and Resection of the Infundibular Stenosis Under Direct Vision Utilizing Controlled Cross Circulation
(Age at Surgery Nineteen Months)

Site	Cardiac Catheterization			
	Preoperative, 1 Mo.		Postoperative, 6 Mo.	
	Oxygen Content,* % Sat.	Pressure, Mm. Hg	Oxygen Content,* % Sat.	Pressure, Mm. Hg
Superior vena cava	19		71	
Inferior vena cava			69	
Right atrium	24	7/2	66	6/2
Right ventricle	39	82/0	(Hi) 66	38/0
Pulmonary artery		8/5	65	20/8
Systemic artery (crying)	25	80/40	94	100/70

* Van Slyke determinations.

cross circulation* and utilization of the patient's father (age 28 years) as the donor. For the operation, this infant was placed upon an electric heating pad to minimize the deleterious cardiac effects associated with any spontaneous drop in body temperature during the perfusion interval. Anesthesia was induced with cyclopropane, and small amounts of thiopental (Pentothal) and nitrous oxide were relied upon for its maintenance thereafter. The chest was entered through an anterior bilateral thoracotomy in the fourth inter-

* References 1 through 5.

space. After the pericardium was opened, the enlarged heart was noted to have that dusky appearance characteristic of severe arterial desaturation. The aorta was large (4 cm.) in diameter, and a small but adequate pulmonary artery (1 cm.) was evident emerging from the right ventricle. A weak thrill was palpable in this vessel. The patient's superior and inferior venae cavae were dissected from the adjacent tissues and encircled by tapes cardiac to the azygos and hepatic veins. The root of the patient's ascending aorta was also encircled by a cotton tape which was attached to a Rumel tourniquet, as previously described.[4] This maneuver by selective occlusion of the coronary circulation, insures an intermittently blood-free intracardiac operating field at will during the cardiotomy. The patient was heparinized (10 mg. intravenously), and the ascending aorta was cannulated with a thin-walled plastic catheter (14 F. diameter) inserted retrograde through the right subclavian artery. The superior and inferior venae cavae were cannulated via the transauricular insertion of similarly sized plastic catheters connected by a stainless steel Y adaptor. Simultaneously, the donor's superficial femoral artery and saphenous vein had been cannulated by similarly sized plastic catheters after his heparinization (1.5 mg. per kilogram of body weight).

The pump was calibrated to deliver 200 cc. of arterial blood per minute from the donor to the patient's aortic catheter and to return from the patient's venae cavae to the donor's saphenous vein the same amount of venous blood for oxygenation. After completion of these preparations, two stay sutures were placed in the right ventricle. The pump reciprocating the interchange of blood between patient and donor was started, and the caval inflow to the patient's heart was occluded by the previously placed tapes. Immediately, there was a dramatic change in the appearance of the heart from that of a deep-blue to a healthy-pink color. The right ventricle was opened by a vertical cardiotomy through the length of its anterior wall. This clearly exposed a ventricular septal defect 25 mm. in diameter, located high in the septum just beneath the aortic valve cusps, which were clearly visible through the defect. There was also a high infundibular stenosis located 5 mm. below the pulmonic valve. This stenotic area had an outflow orifice only 3 mm. in diameter. The cardiotomy incision was extended directly through this narrowed area to lay it widely open. First, the ventricular septal defect was closed by tying five interrupted 000 silk stitches placed carefully between its opposing margins. Then the infundibular muscle obstructing the right ventricular outflow tract was resected generously (Fig. 3). A Hegar dilator (15 mm. diameter) was kept in the pulmonary outflow tract while the cardiotomy was closed with a continuous 000 silk stitch sewn in two layers. The empty heart continued to beat at a slow regular rate throughout this procedure.

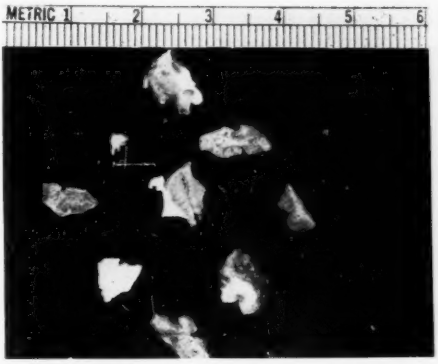

Fig. 3.—Infundibular muscle resected at the time of open cardiotomy in correcting this patient's right ventricular outflow obstruction. The ventricular septal defect was closed with five interrupted stitches of 000 silk.

The making of the cardiotomy and the closure of the ventricular septal defect required a period of six and one-half minutes. The infundibular muscle was then resected and the cardiotomy incision closed with release of the vena caval flow into the heart at nine and one-half minutes. The pump was shut off at 11 minutes and 51 seconds. At this time the patient's heart action was excellent and the blood pressure was 100 mm. Hg. The heart now had a healthy normal pink color.

The caval catheters were removed, and the auricular incisions were oversewn. The subclavian artery catheter was removed and that vessel ligated. The pericardium was loosely approximated, and the chest was closed with two drainage catheters. The patient's measured blood loss during the operation, which lasted 2 hours 30 minutes, was 600 cc., including that volume aspirated from the interior of the heart during cardiotomy. This quantity had been synchronously replaced by an intravenous transfusion of citrated bank blood. The patient's weight at the conclusion of the operation was 8460 gm. as compared with 8550 gm. immediately preoperatively. Therefore, the child was transfused with an additional 90 cc. of blood before being moved from the operating room. The patient was given 0.5 gm. of calcium gluconate intravenously, but no protamine was deemed necessary. The patient's bleeding and clotting time at the end of the operation were 6 minutes 30 seconds and 6 minutes, respectively, as compared with 6 minutes 10 seconds and 2 minutes 30 seconds preoperatively. The preoperative hemoglobin was 19.1 gm. per

100 cc., and that taken at the conclusion of surgery was 14.7 gm. per 100 cc.

A dramatic improvement in the patient's oxygenation was evident from the appearance of the intrathoracic tissues. This impression was confirmed when the surgical drapes were removed at the conclusion of the surgical procedure and the infant's color was seen to be normal.

The donor's plasma hemoglobin taken 30 minutes after the perfusion was 15 mg. per 100 cc. The donor's convalescence was uncomplicated, and he was discharged from the hospital 36 hours after the surgery.

The infant's convalescence was gratifyingly uncomplicated, and 48 hours after surgery he was removed from the oxygen tent that he had occupied since admission to the hospital, 45 days earlier. On the 25th postoperative day he was able to sit up alone. This act he had been unable to do since the age of 14 months (Fig. 1*B*). His brachial artery oxygen saturation on Dec. 29, preparatory to his discharge, was 94%.

Jan. 26, 1955, the patient was seen in the Out-Patient Clinic. He was clinically normal and his color was normal. He was now standing alone and weighed 9500 gm. Digitoxin therapy was discontinued. Chest roentgenograms showed a reduction in the heart size as compared with that of the preoperative studies (Fig. 2*B*). The child returned to the hospital May 23, six months after corrective surgery for cardiac catheterization and other follow-up studies. His age was now 25 months, and he weighed 10.6 kg. He was clinically normal. His mother stated that he was walking, played all day without apparent fatigue, was as active as his normal siblings, and never appeared cyanotic. Physical examination was negative except for the surgical incision and a Grade 2 systolic murmur without a thrill along the left sternal border. The postoperative cardiac catheterization measurements confirmed the clinical impression that the child's cardiac anomalies had been wholly corrected and that his circulation was now normal physiologically (Table). This child's improvement has continued, and at his most recent clinic visit nine months after surgery he weighed 12 kg. and his mother volunteered that he was now more active than his brothers.

Comment

The advent of a reliable technique † for total bypass of the heart and lungs during prolonged periods has made possible the performance of curative surgery for a variety of cardiac lesions (ventricular septal defects, atrioventricularis communis, and tetralogy of Fallot defects). Without a direct-vision intracardiac approach they have remained incurable.

Since March 26, 1954, this technique of controlled cross circulation has been utilized for reparative surgery under direct vision in 45 consecutive patients suffering from these abovementioned defects. There has been no donor mortality in this series. Among those patients with cyanotic congenital heart disease successfully managed by this method was a 2-year-old girl with atresia of origin of the main pulmonary artery. In her case [6] it was possible after closing the ventricular septal defect to anastomose the pulmonary artery to a newly created opening at the top of the right ventricular outflow tract.

From the knowledge and experience gained in these 45 direct-vision intracardiac operations with use of the cross circulation method for support of the patient, it has been possible to develop a simple, disposable, inexpensive, artificial oxygenator ‡ to replace the human donor, without sacrifice of the safety and effectiveness so inherent in the donor method. Subsequently, with use of this oxygenator and the same pump used for the cross circulation operations, 44 patients ranging in age from 4 months to 21 years have had their hearts and lungs totally bypassed for intervals up to 50 minutes during direct-vision intracardiac correction of their defects (ventricular septal defects, atrial septal defects, atrioventricularis communis, tetralogy of Fallot, and complete transposition of the great vessels).

The patient herein reported is unique in that he is the initial patient to have the tetralogy of Fallot defects corrected with objective postoperative studies to corroborate his normal clinical appearance.

Upon the basis of these gratifying successes as well as from the instructive failures, we have adopted the curative operation as the method of choice for all patients with the tetralogy of Fallot defects who are in

† References 1 through 5.

‡ References 7 and 8.

need of surgical help at this time. For urgently ill patients located in clinics where the curative operation may not be available, as yet, the anastomotic operation without opening the pericardium is recommended only if the patients cannot be tided over by nonoperative management until the completely corrective operation becomes available to them.

Addendum

Continuing experience with the completely corrective operation has confirmed it as the most desirable procedure for patients with the tetralogy of Fallot defects in need of operative treatment.

At this clinic no anastomotic procedures for tetralogy have been deemed necessary during the two years since the advent, in August, 1954, of curative surgery for these defects.

During this interim, as indicated in the text, the effective simple oxygenator has supplanted the cross circulation technique for oxygenation. Among the 130 patients operated upon to date with total body perfusion utilizing this pump oxygenator, there have been 29 patients with the tetralogy defects having the corrective operation, with 20 successes. Careful analysis of our failures, particularly, has resulted in substantial additions to our knowledge about the pathological anatomy and techniques for its correction, with a consequent steadily decreasing operative risk for the patients.

The commonest cause of death or failure was failure to completely relieve the pulmonary obstruction coincident with the complete closure of the ventricular defect. This problem, in the severe tetrads with very hypoplastic outflow tracts where it is not anatomically possible to resect sufficient infundibular muscle, has been readily managed, since its recognition, by use of an appropriately sized piece of compressed polyvinyl sponge (Ivalon) sewed into the ventriculotomy incision as a roof to further enlarge the right ventricular outflow tract.

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Calcification in the Portal Vein

Report of Two Cases

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Reported cases of calcification in the portal vein or its tributaries are few. Magovern and Muehsam [1] in reporting a patient with extensive calcification in the portal and splenic veins noted that only 21 cases had been recorded in the past 50 years. The first case to be diagnosed roentgenographically and proved at surgery occurred in 1948.[2] In the patient described by Magovern and Muehsam, diagnosis was made roentgenographically and confirmed later at autopsy. None of the patients have been subjected to portacaval anastomoses.

Because of the few cases available for analysis, it was thought worth while to report two cases encountered at the New York Hospital with calcification in the portal vein or tributaries. Both patients were subjected to surgery and have been followed postoperatively. It is hoped that when suitable numbers of cases are available for study, the possible explanation for this phenomenon may be reached.

Report of Cases

CASE 1.—This 33-year-old white man was admitted to the New York Hospital because of esophageal varices.

His present illness began 16 years prior to admission, 1934, at which time, while engaged in physical activity, he had sudden epigastric pain and vomited a large amount of coffee-ground material. He had melena following this. Without treatment the episode subsided, and he was well until 1935, when he again bled. He recovered from this in about two weeks. One year later, 1936, he had hematemesis again, but this time it was associated with jaundice. He was admitted to the New York Hospital for the first time on Oct. 28, 1936, where work-up revealed Banti's disease, and he underwent splenectomy. At operation the spleen was enlarged. The liver was noted to be enlarged and had evidence grossly of early cirrhosis. No mention was made concerning phlebosclerosis. His postoperative course was complicated by hematemesis and melena, which subsided under conservative management.

Following discharge he was well until 1939, when he had two episodes of hematemesis which responded to conservative measures. He had no further bleeding after this until 1949, when he was hospitalized elsewhere and required four transfusions for gastrointestinal bleeding. Esophageal varices, not present before, were noted on x-ray, and he was admitted to the New York Hospital on March 15, 1950, for further evaluation. He had had no jaundice, abdominal pain, nausea or vomiting, anorexia, ascites, melena, hematemesis, or weight loss since his last episode of bleeding in 1949.

Physical Examination.—The patient was a well-developed, well-nourished white man in no acute or chronic distress and without evidence of jaundice.

His temperature was 98.6 F (37 C), pulse rate 80 per minute, respirations 18 per minute, and blood pressure 130/80. Examination was completely unremarkable except for minimal varicose veins over the lower extremities and a healed left upper rectus incision. The patient had no ascites or abdominal tenderness. His liver was not enlarged.

Laboratory Data.—Complete Blood Count: Hemoglobin 14.5 gm. per 100 cc.; red blood cell count 4,300,000 per cubic millimeter; white blood cell count 9000 per cubic millimeter with normal differential.

Urine: Unremarkable.

Stool for Occult Blood: 3+ and 4+ during hospitalization, and 1+ at time of discharge.

Sulfobromophthalein Sodium (Bromsulphalein): 6.4% retention on admission.

Serum Bilirubin: 1.2 mg. per 100 cc.

Cephalin Flocculation: 3 units.

Bleeding, clotting, prothrombin time, B.U.N., CO_2, Cl, protein with A/G ratio, alkaline phosphatase, and thymol turbidity were within normal limits.

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From the Department of Surgery, the New York Hospital-Cornell Medical Center.

X-ray: Gastrointestinal series was normal in ragard to stomach and duodenum, but esophagram revealed esophageal varices.

Course.—At operation, March 27, 1950, the liver was found to be slightly nodular with areas suggesting regeneration together with scar formation. There was marked edema in the subhepatic area and increased vascularity about the subportal structures. Veins in the mesentery were prominent. Portal pressure measured in one of these was 280 mm. of saline. Palpation of the portal vein revealed areas of calcification. After dissection, the portal vein proved to be a very short wide structure with calcification in its wall. A projection of the caudate lobe between the portal vein and the inferior vena cava made portacaval anastomosis impossible. Therefore, an anastomosis was performed between the superior mesenteric vein and the inferior vena cava. Repeat portal vein pressures following the shunt revealed no appreciable decrease.

Biopsy of the liver revealed it to be divided into numerous large nodules by bands of fibrous tissue. There was distortion of the liver lobules in the nodules, with eccentricity of the central vein in some areas. There was remarkably little cellular infiltration of the portal areas (Fig. 1).

The small section of mesenteric vein excised from the site chosen for anastomosis was composed of dense hyaline tissue, a part of which was calcified (Fig. 2).

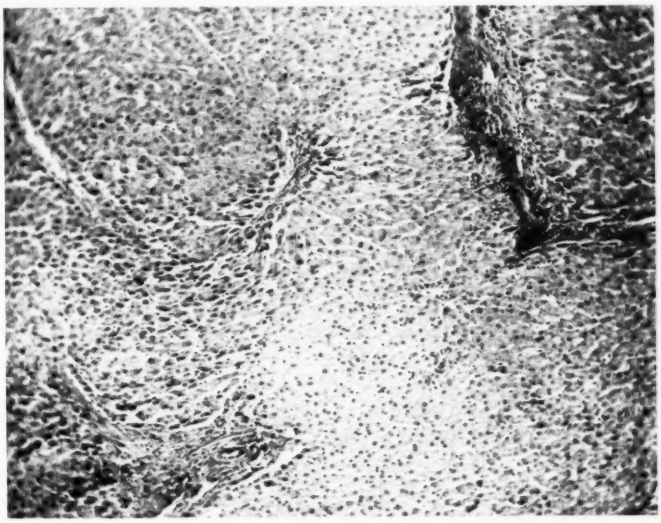

Fig. 1. (Case 1).—Liver biopsy. The liver parenchyma is somewhat distorted, but there is remarkably little fibrosis or cellular infiltration in the portal areas. Reduced slightly from mag. × 90.

Fig. 2. (Case 1).—Section from the superior mesenteric vein. The vein wall is composed of dense hyaline tissue which is calcified in part; the darker, fragmented areas represent calcific deposits in the wall. Reduced about ⅓ from mag. × 27.

The patient's postoperative course was marked by upper gastrointestinal bleeding that began on the 13th postoperative day. During the next six days 2000 cc. of whole blood was given by transfusion. Following this bleeding ceased, and 24 days after surgery the patient was discharged.

About three months following discharge the patient had another bleeding episode and was readmitted. He required 1500 cc. of blood, and an esophageal tamponading balloon was necessary to control the bleeding. The balloon was in place under a pressure of 25 to 30 mm. Hg for three days. Several days later he was discharged.

In 1952, two years after the last episode, he again bled, but this time transfusions were not required. Liver function studies performed on both of these later admissions were within normal limits. X-rays of the esophagus revealed persistent large varices.

Since his discharge three years ago, the patient has had no further bleeding. At last examination his liver was 1 fingerbreadth below the right costal margin. He had no ascites, jaundice, liver palms, or spider hemangiomata.

CASE 2.—This 29-year-old white woman was admitted to the New York Hospital in May, 1954, for a portacaval shunt because of marked gastric and esophageal varices.

About 12 years prior to this admission, 1932, she had had hematemesis and melena. She was hospitalized for about one month, and gastrointestinal series at that time was said to have revealed a "stomach ulcer." Bleeding ceased, and about nine years prior to admission, 1935, she had another episode of hematemesis. She was hospitalized and given 4000 cc. of blood. At that time a gastrointestinal series was unremarkable, and work-up revealed an enlarged spleen. Because of this she underwent splenectomy. The liver was reportedly normal at operation.

Following this the patient had no further episodes of bleeding. She married and had two normal full-term pregnancies.

In 1952 she once more had tarry stools and required hospitalization and blood transfusions. A gastrointestinal series during her hospital stay suggested a duodenal ulcer. When bleeding ceased, she was discharged on an ulcer regimen. Following this she was well for about two weeks but then had apprehension, hematemesis, and tarry stools. She was rehospitalized and required transfusions. Repeat gastrointestinal series again was thought to show a duodenal ulcer, but in a location different from that previously noted. She had normal liver function studies and was not icteric. There were no varices on the esophagram.

The patient was admitted to the New York Hospital for the first time, where gastrointestinal x-rays revealed small esophageal and gastric varices. The liver was 2 fingerbreadths below the right costal margin. Work-up was otherwise unremarkable.

On July 3 she had an exploratory laparotomy. The liver was observed to have changes suggestive of early cirrhosis. Portal pressure was 200 to 210 mm. of saline, and portal venogram failed to show extrahepatic block. Because portal pressures were not significantly elevated, a portacaval anastomosis was not done. No pathologic changes were noted on the biopsy specimen of liver.

Following this the patient was readmitted twice in 1953 and again in 1954 for episodes of tarry stools, and each time she was treated by transfusions. Liver function studies revealed no abnormalities. In each instance x-ray examinations revealed gastric and esophageal varices. Because of the recurrent bleeding episodes and persistent varices on x-ray studies, she was admitted on May 16, 1954, for portacaval anastomosis.

Physical Examination.—On admission the patient was a well-developed, well-nourished white woman, not appearing acutely or chronically ill or jaundiced.

Her temperature was 98.6 F (37 C), pulse rate 80 per minute, respirations 20 per minute, blood pressure 110/70. The remainder of the examination was unremarkable except for liver enlargement 2 to 3 fingerbreadths below the right costal margin. She had no ascites, jaundice, liver palms, or spider hemangiomata.

Laboratory Data.—Complete Blood Count: Hemoglobin 11.5 gm. per 100 cc.; hematocrit reading 38; white blood cell count 5400 with normal differential.

Urine: Unremarkable.

Stool for Occult Blood: 1+ on one occasion; negative on three occasions.

Liver Function Studies: Bilirubin: 0.4 mg. per 100 cc. Cephalin flocculation: 7 units. Prothrombin time, total protein with A/G ratio, B.U.N., CO_2, Cl, Na, and K were within normal limits.

Course.—On May 18 a portacaval anastomosis was performed. At operation the portal vein was attached to surrounding tissues by adhesions and excessive amount of fibrosis. As the portal vein was further dissected, it was found that inferiorly, as it came out of the pancreas, there was an obvious plaque of calcium in its wall. The vein, because of this finding and because of the dense adherence to the surrounding tissues, was not normal, and it was thought that possibly it might be occluded by a thrombus. This would be in contradiction to the portal venogram taken in 1952. However, dissection was continued until 3 to 4 cm. of portal vein was exposed circumferentially. The inferior vena cava was prepared for anastomosis. The portal vein, when divided, was patent, and the intimal aspect was smooth. However,

along the right lateral edge was a heaped-up zone of medial and intimal thickening, resembling an atheromatous plaque. This was cephalad of the previously palpated zone of calcification. An end-to-side portacaval anastomosis was then performed, with use of the greatly hypertrophied or sclerotic area of portal vein. In palpating the anastomosis after its completion, a good compressible oval existed superiorly. Inferiorly, however, the lumen was obviously compromised by the thickened portion of vein described above. Portal pressure was 25 cm. of saline before the shunt and fell to 13 cm. of saline after the anastomosis.

Biopsy of the liver revealed no abnormalities and specifically no evidence of cirrhosis.

The section of portal vein excised showed bundles of smooth muscle in association with intervening fibrous tissue, which stained deeply pink and was relatively acellular.

Postoperatively the patient did well except for slight evening temperature elevation during the first nine days. After this the temperature remained normal, and she was discharged on the 14th postoperative day.

Since discharge she has had no further episodes of bleeding. Esophagram one year after operation revealed no evidence of varices.

Comment

Postoperatively, Patient 1 has done poorly, as might have been predicted, for there was little drop in portal pressure following the anastomosis of the superior mesenteric vein to the inferior vena cava. The wall of the vessel used in the anastomosis was calcified. Subsequent course suggests that the sclerotic area was not bypassed, and, indeed, may have progressed. His varices persist throughout the thoracic esophagus.

In Patient 2, in whom a partly hyalinized portal vein was used for the portacaval shunt, a good fall in portal pressure was obtained. Her subsequent course suggests that progression of the process has probably not occurred.

The cause of sclerosis of the portal vein is unknown. Earlier writers * placed great emphasis on syphilis as the etiologic agent. Banti † thought that atheromatous-like plaques in the portal vein resulted from a sclerotic endophlebitis. Saxer [5] considered sclerosis the result of thrombosis, while Spiegelberg [6] and Borrmann [7] considered sclerosis the forerunner of thrombosis. Primary sclerosis of the portal vein was reported by Buday,[8] Hart,[9] and Winkler.[10]

The possibility of sclerosis being secondary to hepatitis with spread into the portal vein is discussed by Magovern and Muehsam.[1] In the two cases reported in the present article, neither of the patients had a history suggestive of hepatitis at any time. There was no evidence of syphilis nor did the portal veins contain a thrombus. It is interesting to speculate on increased portal pressure causing vein wall injury with subsequent hyalinization and calcification. However, in both of the patients reported, the portal pressure was not markedly elevated, and, if this supposition were correct, sclerosis of the portal vein would be seen in more cases of portal hypertension. The liver in Case 1 revealed only minimal fibrosis and evidence of portal cirrhosis. In Case 2 the liver was normal on microscopic section. On this basis then, the portal hypertension and associated gastric and esophageal varices do not seem to be secondary to cirrhosis, but possibly are due to the narrowing of the portal vein from the sclerotic process. This suggests that the etiology of the sclerosis was not the hypertension, but rather that the sclerosis might be the probable cause of the hypertension. The pathogenesis of the portal sclerosis in these cases cannot be outlined. In the absence of a history of hepatitis or syphilis and with the minimal findings of cirrhosis, it is likely that none of these played a role in the development of the sclerosis. Whether the patients had subclinical attacks of hepatitis, which led to vein wall injury and subsequent hyalinization and calcification, is a matter for conjecture.

Summary

Two cases of sclerosis of the portal vein are reported in which portacaval anastomosis was performed.

* References 3 and 4.

† Banti, cited by Trevor.[4]

The various etiologic factors thought to lead to sclerosis of the portal vein are discussed.

The postoperative courses in the cases reviewed are presented.

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Correspondence

LIGATION OF INFERIOR VENA CAVA AFTER NEPHRECTOMY

To the Editor:—When we wrote our article called "Ligation of the Inferior Vena Cava After Nephrectomy," published in the February, 1956, issue of the A. M. A. ARCHIVES OF SURGERY, we were unaware that it was to be considered a discussion of the procedure of ligation of the vena cava, in general. We appreciate Dr. Dodson's comments very much, but we believe that they require a little clarification so that our article should not be presented in anything other than the light in which it was intended.

We realize that our drawing is slightly misleading in that it shows the presence of a residual stump of the right renal vein. This is done merely to show the anatomical relationship of the ligature on the vena cava as regards the normal position of the right renal vein. It is to be noticed that we present this as one case in a large experience, and we certainly do not present it as the method of choice of controlling hemorrhage from the renal veins. At any time that the veins can be transfixed and ligated, or the vena cava repaired, we well realize that this is the method of choice.

The misunderstanding, then, revolves around the fact that this patient, due to infection, had a tremendous hematoma, as shown in the lateral view of our Figure. There was not only complete absence of the stump of the renal vein, but there was an erosion or hole into the vena cava which did not lend itself to repair, due to its friability from the chronic low-grade infection. So much, for our case.

In Dr. Dodson's editorial, he makes the statement that it would be preferable to leave clamps in the wound rather than to ligate the vena cava; and, in another place he says that "although . . . the inferior vena cava may be safely ligated, it is a drastic procedure." We believe that this statement requires some clarification because it is our sincere feeling that, in the presence of large pulmonary emboli, the "failure" to ligate the inferior vena cava is a drastic procedure. We have tried minor ligations in the presence of these phenomena, and only one year ago, one of us (R. M. B.) ligated a right common iliac vein in the presence of repeated pulmonary emboli only to have the patient die four days later from a silent thrombophlebitis in the other extremity. We have, therefore, come to feel with Homans that thrombophlebitis is, in most cases, a bilateral disease, even when no symptoms exist on one side or the other; and we have seen people die of fatal pulmonary emboli with thrombophlebitis or phlebothrombosis, demonstrated at autopsy, when, indeed, there was never at any time a single leg sign present.

We have come to believe, then, that if anything is to be ligated—and we prefer to treat these things by ligation—it should be only the inferior vena cava, and nothing less. Our experience with 39 vena cava ligations leaves us only one death, that in a patient 79 years of age who had previously had a suprapubic prostatectomy and had advanced myocardial disease.

We believe that the indications for ligation of the vena cava should very definitely be present before such procedure is undertaken; but, when the indications are present, we believe that not to ligate the inferior vena cava is drastic. We believe that Dr. Dodson has exaggerated the danger of vena cava ligation beyond its proper position. We do not believe that it is a dangerous procedure, and we have done it as a follow-up procedure in practically any general surgical measure that you can mention. We have never had a patient die of pulmonary embolism following ligation of the inferior vena cava. We have not had a patient disabled by edema following the ligation. It is to be understood that some of these people do have some swelling of the ankles which is easily controlled by elastic stockings, but that one must be alive in order to wear elastic stockings.

Again, we want to thank Dr. Dodson for his fine editorial, and to tell him that, until his editorial appeared, we did not know that our article was to be discussed from the standpoint of ligation, in general, but we appreciate this opportunity to discuss the problem with him and to state our side of the question. We agree with Dr. Dodson that this procedure, which we

Specialists certified by the American Board of Surgery (Drs. Bolman and Lloyd); Fellow, American College of Surgeons (Dr. Bolman).

recommend, is only to be used when ligation or suture-ligation is not feasible. There will be cases where this thing recurs, and, when those procedures are not feasible, we certainly do believe that a clean surgical ligation of the vena cava is much to be preferred over something which leaves clamps on a friable vessel in a field where one can scarcely be certain of what one is clamping. We appreciate the opportunity to answer his editorial.

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Combined Operations For
Intra-oral Carcinoma
And Cervical Metastasis

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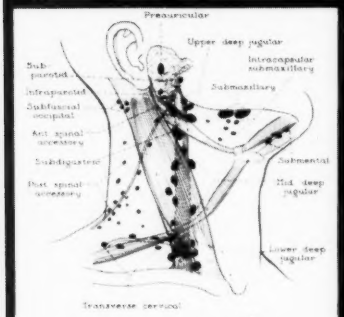
Radical surgical intervention for the treatment of intra-oral carcinoma and cervical metastasis from these lesions has become feasible and safe in recent years. Both primary and metastatic lesions can be removed during the same operation as a combined procedure. If necessary, en bloc excision should be performed and even hemimandibulectomy carried out if indicated. Dissection of the neck for metastatic lesions always should be radical.

This exhibit presents (1) the clinical appearance and salient pathologic features of various types of malignant intra-oral and cervical metastatic lesions, with the aid of illustrative cases, (2) the surgical anatomic features of the oral cavity and the neck, (3) indications for surgical procedures and (4) results of treatment.

Neck Dissection For
Metastatic Lesions
And Removal of the Primary Lesion

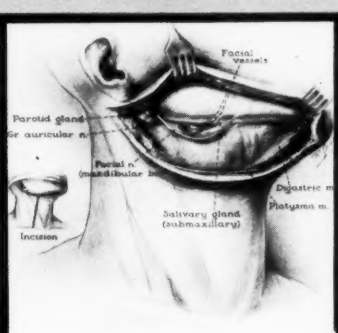
Dissection of Neck and Treatment of Primary Lesion Should be a Combined Procedure

In treating labial, oral or laryngeal carcinoma, dissection of the neck, when indicated, should be carried out simultaneously with the treatment of the primary lesion as a combined procedure. The contents of the neck and the primary carcinoma may be removed separately but, if anatomically possible, en bloc dissection of both is preferable. Excision of the primary lesion should be wide and include a proved margin of normal tissue about the lesion; if any dissection in the neck is indicated, it should always be radical in type.



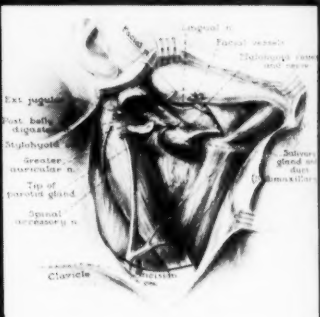
Nodes to Be Removed

A radical neck dissection for labial or intra-oral carcinoma should remove all the nodes shown except the preauricular nodes. In the dissection, the tissues that are sacrificed should be removed en bloc.



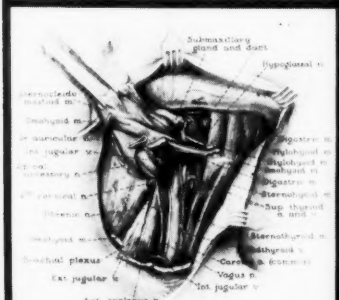
Suprahyoid Incision

Suprahyoid incision is made first, and neck structures to be removed are freed from the lower border of the mandible. The mandibular branch of the facial nerve is preserved unless the adjacent tissues are involved.



Vertical Incision

A vertical incision is extended to the clavicle and skin flaps retracted. The platysma muscle, if not involved by the tumor, is usually preserved and left attached to the skin flaps.

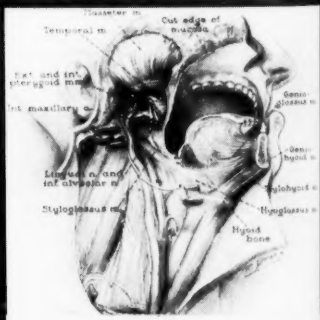


Sternocleidomastoid and Omohyoid Divided

Sternocleidomastoid and omohyoid divided and retracted, exposing the brachial plexus, scalene muscles and large vessels. Internal jugular vein is divided and elevated. Digastric muscle and contiguous structures are freed from mandible.

Dissection Completed

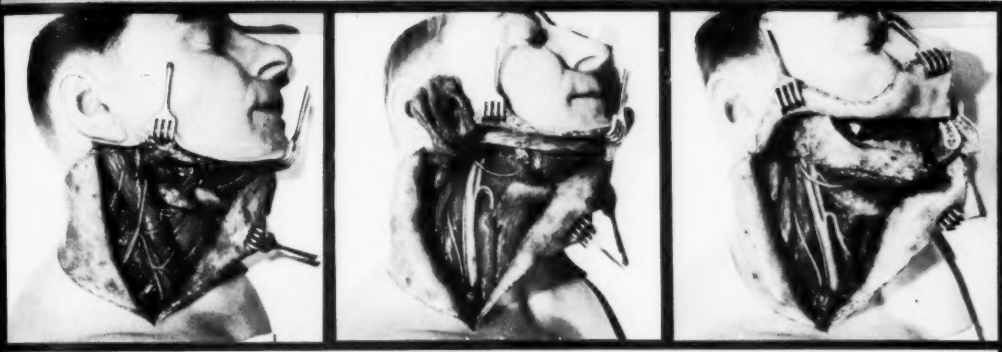
The internal jugular vein divided and ligated as close to the jugular foramen as possible. The hypoglossal, lingual, vagus or phrenic nerves may be excised if necessary. Carotid vessels may also be sacrificed if invaded by the carcinoma.



Hemiglossectomy and Hemimandibulectomy

Hemiglossectomy, hemimandibulectomy and excision of the floor of the mouth have been completed. This should be done en bloc with the neck structures but may also be done independently of these tissues at the same operation.

Neck Dissection (Cont.)



In a radical dissection of cervical structures, all tissues that can be sacrificed are removed en bloc, leaving only the carotid arteries and certain tissues.

Postoperative Care

1. Antibiotic therapy (usually penicillin 600,000 units daily) to prevent infection.
2. Anticoagulant prophylaxis beginning the fourth postoperative day in all cases.
3. Early ambulation beginning day of surgery.
4. Frequent use of tracheostomy to insure an adequate airway. Especially indicated following hemimandibulectomy or bilateral neck dissection.
5. Maintenance of nutrition by intravenous infusions and by nasal-tube feeding as soon as possible.

Type of Anesthesia

General anesthesia (usually sodium pentothal) and a cuffed intratracheal tube are used.

Blood transfusions are given as indicated.

Temporary tracheostomy is established frequently to assure an adequate airway.

Mortality

Mortality rate from neck dissection alone is less than 1 per cent and for combined procedures 3 per cent.

Hospitalization for patients on whom neck dissection alone is carried out is 3 to 5 days and for those on whom a combined operation is done is 7 to 10 days.

Indications For Neck Dissection

1. When clinically positive or proved positive cervical metastatic lesions are present, regardless of location of the primary lesion.

2. When it is necessary to expose the lateral neck for a hemimandibulectomy, even though the cervical nodes do not appear to be metastatically involved.

3. When the primary lesion is in the tongue, floor of the mouth, cheek and laryngopharynx, regardless of evidence of clinical metastatic involvement.

Bilateral Radical Neck Dissection

A bilateral neck dissection (simultaneous or two-stage) is frequently indicated and justifiable when metastatic lesions are present bilaterally. The procedure can be carried out with safety.

Simultaneous neck dissection is indicated when it is felt that the side not operated upon may become inoperable before the second stage can be done.

Cyanosis of the head is frequently present for 3 to 7 days postoperatively. Marked edema of the face may appear as the cyanosis disappears. This condition, too, gradually disappears but not completely.

Illustrative Cases

Early Treatment is Most Essential

The best time to treat intra-oral carcinoma is during the early, localized stage. This implies an alert lay group and a high index of suspicion among the medical and dental profession. Precancerous lesions, such as leukoplakia and epithelial hyperplasia, should be removed before obvious carcinomatous changes occur.

One should not advocate radical surgical procedures, with their functional and cosmetic deformities, except when absolutely necessary. Unfortunately, many patients come to surgeons with extensive or recurrent lesions that make radical combined resections necessary.

Carcinoma of the Tongue

Woman, 53 years old. "Smarting under the tongue" for 4 weeks. Ulcerative lesion 2.5x3 cm. along left border of middle third of tongue. Treated by combined radical neck dissection and hemiglossectomy by pull-through procedure, preserving the mandible. Pathologic report: grade 2 S.C.E. No recurrence 25 months postoperatively.

The Lesion

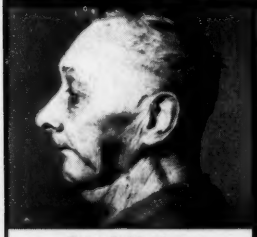
The Tongue 12 Days After Removal of Lesion

The Tongue 3 Months After Removal of Lesion

Minimal Deformity Following Neck Dissection

Carcinoma of the Floor of the Mouth and Tongue

Man, 57 years old. "Growth in mouth" for 3 months. Lesion involved floor of mouth, extending to lateral margin of tongue. Treated by combined radical neck dissection, hemiglossectomy, hemimandibulectomy. Pathologic report: grade 2 S.C.E., 2.5x2.4 cm. Mandible not invaded. Cervical lymph nodes negative. Three months later, early S.C.E. excised locally from opposite floor of mouth. No recurrence 10 months postoperatively.



Scar Following Combined Operations

Surgical Specimen

Minimal Deformity Following Hemimandibulectomy

Patient in Good Health 8 Months After Operation

Illustrative Cases

Carcinoma of the Jaw

Man, 51 years old. A lesion 4x2x2 cm. involved the right mandible and caused numbness of lower jaw. Roentgenograms showed destruction of mandible near the angle. Biopsy: grade 2 S.C.E. Treated by radical neck dissection and hemimandibulectomy. Patient had good occlusion without prosthesis. No recurrence 20 months postoperatively.

Preoperative Appearance

Destruction of Mandible Near Angle

Minimal Deformity No Prosthesis Used

Good Occlusion in Spite Of Hemimandibulectomy

Carcinoma Base of the Tongue and Epiglottis

Man, 67 years old. Dysphagia for 1 year. Bilateral lumps in the neck 3 months. Extensive ulceration involving base of tongue, extending into epiglottis; bilateral metastatic masses. Bilateral simultaneous radical neck dissection, total laryngectomy and excision of base of tongue. Pathologic report: gr. 2 S.C.E. of base of tongue with bilateral metastatic masses. No recurrence 3 years postoperatively.

Appearance of Wound Before Closure

Postoperative Specimens

Closure of Wound: Note Type of Incision

In Good Health 3 Years After Operation

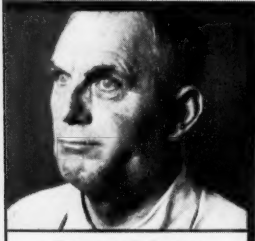
Illustrative Cases

Indication for Mandibulectomy

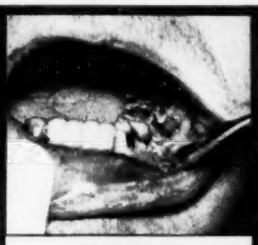
In treating intra-oral carcinoma, the strongest indication for removing the mandible is invasion of bone by cancer. Other indications depend upon the proximity of carcinoma to the mandible, the problem of closure of the oral cavity and the surgeon's judgment. When there is invasion of bone by carcinoma, disarticulation is performed. When there is no invasion, segmental resection may be performed. The proximal mandibular segment, however, adds nothing to the cosmetic result. Disarticulation is better if reconstruction of the bony defect is not planned. None of our patients have had foreign bodies inserted in the form of a prosthesis, nor have any of them requested bone grafting later.

Carcinoma of the Cheek and Jaw

Man, 65 years old. Ulcerated lesion on outer surface of left mandible, 7 cm. in diameter, which started as a "gum boil" 5 months previously. Biopsy showed grade 2 S.C.E. Treated by combined radical neck dissection and left hemimandibulectomy. Full-thickness involvement of cheek required preoperative planning of large cervical flap for closure of defect. Mandible was negative roentgenologically but was involved histologically. No recurrence 13 months postoperatively.

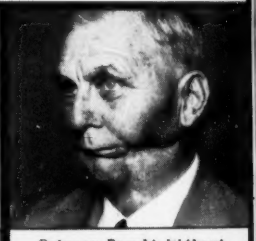


Intra-oral Lesion Involving the Skin



Invasion of Alveolar Ridge

Surgical Specimen



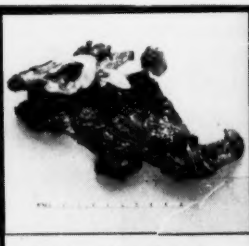
Primary Result Without Use of Multiple Procedures

Carcinoma of the Alveolar Ridge

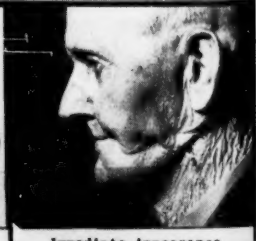
Man, 72 years old. A "sore in mouth" for 6 weeks. Biopsy showed grade 3 S.C.E. Roentgenogram of mandible was negative. Treated by combined radical neck dissection, hemimandibulectomy. Pathologic report: ulcerating grade 3 S.C.E., 2x2x1.5 cm., involving the lingual aspect of the alveolar ridge. Cervical lymph nodes were inflammatory. Mandible was involved histologically. No recurrence 9 months postoperatively.

The Intra-oral Lesion

Negative Roentgenogram



Postoperative Specimen



Immediate Appearance After Combined Operations

Illustrative Cases

Postirradiated Carcinoma of the Lip With Metastasis

Man, 68 years old. Painful ulcerating mass of right cheek with pathologic fracture of the jaw and a cutaneous fistula. Treated by combined radical neck dissection, hemimandibulectomy. Pathologic report: grade 3 S.C.E., 4 cm. in diameter, involving body of mandible and invading submaxillary salivary gland. No recurrence 3 years postoperatively.

Extensive Involvement Perforating Cheek

Pathologic Fracture

Surgical Specimen

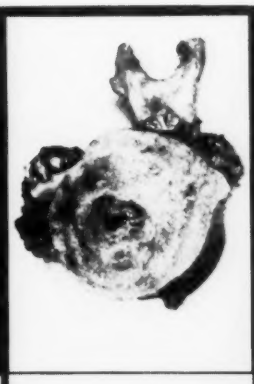
Immediate Postoperative Appearance

Postirradiated Carcinoma of the Lip With Metastasis

Man, 55 years old. Metastatic submandibular mass from cancer of lower lip, previously treated by x-rays. Duration 1 year. Roentgenogram showed malignant destruction of mandible. Treated by combined radical neck dissection, hemimandibulectomy and primary skin graft. Pathologic report: grade 4 S.C.E., 8x7x7 cm. Patient has not been traced.

Fixed Mass Attached To the Mandible

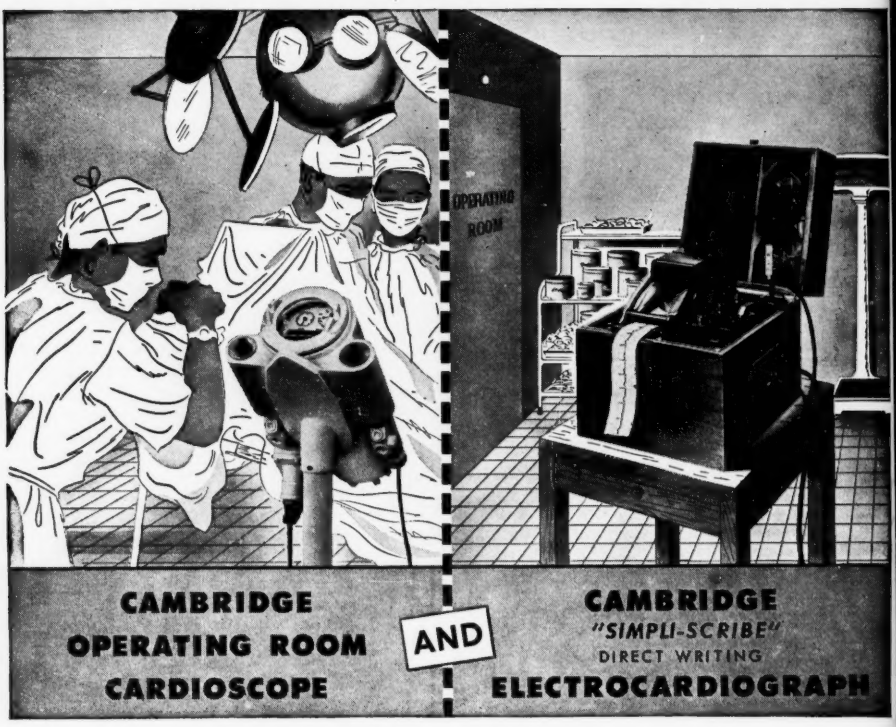
Positive Roentgenogram



Surgical Specimen

Skin Graft 2 Weeks After Operation

Know . . . Don't Guess!



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